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Secondary Science Education

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Winslow · The Integrated School Art Program

SECONDARY SCIENCE EDUCATION

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FIRST EDITION

McGRAW-HILL BOOK COMPANY, INC.
New York Toronto London
1952

SECONDARY SCIENCE EDUCATION

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Library of Congress Catalog Card Number: 51–12656

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PREFACE

This book represents an over-all "job analysis" in terms of philosophy of approach, methods of procedure, and suggested subject content. Designed to complement *Elementary Science Education,*[1] which covers the instructional sequence in grades 1 to 8, inclusive, the present volume completes the survey of science education as a specialized field below the college level.

With relation to teacher training, divergent trends are apparent, two basic course types having become widely prevalent both in undergraduate curricula and in summer sessions emphasizing in-service offerings. Elementary teachers collectively appreciate the *demonstration workshop* idea, where they can assimilate new techniques and at the same time get the feel of personal participation in unit activities while rearranging and correlating their own classroom materials. Music, art, rhythms, social science, language arts, dramatics, mathematics, and natural science are integrated in the daily elementary profile, in sharp contrast to the departmental picture prevailing in the junior-senior high school, even where the core curriculum is operative.

Educators specializing in the teaching of adolescents, on the other hand, uniformly prefer the *seminar* approach, both in undergraduate teacher training and in "refresher"-type summer graduate school courses. In approving the seminar method, the author takes a firm stand on two assumptions. The first of these is a prerequisite technical preparation with regard to basic knowledge and skills, obtained under competent instruction within the maturation framework of the science disciplines. The biologist should have had thorough grounding in the essentials of plant and animal taxonomy, morphology, physiology, ecology, and economics. The physical scientist is assumed to have completed courses at the college level in inorganic and organic chemistry, general physics, historical and physical geology, and meteorology. In making this preliminary assumption, mastery of subject detail and source materials is taken for granted, as well as comprehension of generalized principles in subject fields in which the educator is preparing to offer instruction.

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[1] Wells, Harrington, *Elementary Science Education,* McGraw-Hill Book Company, Inc., New York, 1951.

The second assumption is with relation to what has generally come to be accepted throughout the nation as a broad, general education. Students planning to make preprofessional use of this text, in addition to their correlative lecture-laboratory-field studies in the sciences, should possess in some degree the maturity of viewpoint and breadth of concept which come through even brief preliminary exposure to the tenets of modern psychology, sociology, economics, history, and English, in addition to experiences in the applied arts. Such maturity is essential in youth guidance, which lies at the core of adolescent educational effort, and such breadth of concept is of inestimable value in undertaking social leadership in the classroom.

If these assumptions are valid, there is less need for a professional recipe book detailing manipulative techniques than there is for an applied philosophy in terms of an interpretive survey of principles and trends. In the experience of the author, content knowledge may safely be taken for granted provided prior training has been adequate, but there is a crucial necessity for *orientation* with regard to activities and objectives both in and beyond the secondary school laboratory. There is need for frank, dynamic presentation of opposing viewpoints, resulting in an establishment of perspective which will facilitate intelligent comparison and selection as the science educator enters the secondary school classroom. There is need for analytical appraisal of the *how* and *why* of socialization, environmental coordination, and teacher-student rapport.

Three parallel themes become evident as the chapter sequence unfolds, each branching in dichotomous interrelation to form the warp and woof of the educational pattern presented. The first in this theme triad is the concept of *science-social science interdependence;* the second, an advocacy of *physical science-life science coordination;* the third, a sponsorship of functional *community-industry correlation* with the teaching of science in the secondary school. Each of the three themes is interwoven throughout consideration of the specialized subjects, and the degree to which this text on motives and methods is successful with relation to each double-barreled objective will determine its professional worth.

There is much to learn and much to teach in addition to content materials within major and minor fields. Attitudes toward pure and applied research, maturation of comprehension in terms of historical backgrounds as well as contemporary technological advances, the giving and receiving of constructive criticism, and learning to work together harmoniously in pursuit of knowledge are citizenship-training qualities of significance. In organization and content the viewpoint is that of vicarious practical experience, the atmosphere of the demonstration laboratory being brought before the practice teacher. Often there are type lessons, presented through the eyes of an observer. Usually there are detailed course outlines which administrators, supervisors, veteran teachers, or professional novices may adapt to their own ideas, technical backgrounds, and school environmental conditions. Always there are problems for socialized discussion and review, each chapter being presented as an entity while being correlated with others in the science outgrowth formulation. All arrangements and analyses are oriented in the direction of whole-personality development, character maturation, and preparation for future life experiences of the students enrolled in the science classes of our American secondary schools.

HARRINGTON WELLS

SANTA BARBARA, CALIF.
January, 1952

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PART I

THEORY AND PRACTICE

Chapter 1. THE INTEGRATED SCIENCE PROGRAM

The field of science education is comparatively new. Professorships in many of our leading colleges and universities have only recently been established, and integrated programs of teacher training in science coordinated with in-service "refresher" courses in terms of need. The frontier has attained top-level recognition, however, through leadership in such centers as Stanford, Columbia, Cornell, Illinois, Ohio State, Michigan, Nebraska, Chicago, Purdue, Harvard, Oregon State, and Minnesota, and is widely heralded by secondary school teachers throughout the nation.

PRELIMINARY SURVEY

Prominent American educators are devoting serious attention to the development of effective methods of secondary school instruction, their efforts having resulted in a steadily increasing tendency to stress the desirability of an extended unified program of dynamic, functional training. A general core curriculum based upon community-school-industry integration, amplified into major areas of experience and skills such as *science education,* is the theme today, with conscious attention being given to philosophy of human contacts as well as to social correlation in a specific minor area of concentration such as the junior-senior high school.[1]

One of the prime functions of secondary science education being to lay foundations for and to establish desirable attitudes toward employment of the scientific method and the objectives of advanced research, the manner and means of orientation assume relative importance in terms of preparation of teachers for student viewpoint coordination as well as subject-matter integration. It must be clearly stated at the outset of our investigations into procedures at the secondary school level, and reiterated throughout the chapter presentations which follow, that the integrated science program is basically one of long-range preparation for adult living in an American democratic society, coordinated with the world social order.

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[1] Benjamin, Harold, "American Education in the Twentieth Century —Second Half," *Third Yearbook of the American Association of Colleges for Teacher Education,* Oneonta, N.Y., 1950.

The kaleidoscopic nature of contemporary national and world events influences modern science education to a tremendous degree, and vice versa, for preparation of socially aware instructors will not only provide for future leaders in scientific fields but for an informed adult citizenry as well. The interdependence of medicine and industrial technology on the one hand and pure and applied science on the other has been made abundantly clear both through academic exposition [2] and general analyses of world trends presented through such popular media as the radio, magazine, and newspaper present in American homes. There is no debate among educational leaders regarding the pertinence of an integrated developmental program of science training in terms of sociological trends.[3]

Opposition

As has been the case with most transitional movements throughout the history of education, however, there is current resistance to progressive change in some divisions of higher education. There is constructive criticism as well, directed chiefly at secondary science teaching in terms of fundamentals, but aimed also at the lower division college and university level.[4] Suggestions from those with perspective, vision, insight, and breadth of concept are of tremendous value with relation to healthful development. Awareness of and attention to destructive comment, moreover, will result in careful progress, watchful of error, avoiding and eliminating pitfalls indicated through oral and written antagonism.

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[2] Conant, James B., "The Impact of Science on Industry and Medicine," *American Scientist*, Vol. 39, No. 1, January, 1951.

[3] Laton, Anita D., and Powers, Samuel R., *New Directions in Science Teaching*, McGraw-Hill Book Company, Inc., New York, 1949.

No one familiar with the American system of higher education will deny the general friction and mutual distrust often existent between the faculties of our schools of education and the men and women of science. According to the views of some scientists, the professional educator is entirely too profligate in his coinage of high-flung phrases, such as "core curriculum" and "societally significant." He is wont to speak glibly of "supporting data," yet fails to document his writing or to statistically support his own research. He sometimes lacks adequate numbers in sampling and does not always employ proper experimental controls. He has been known to advocate blanket promotion so as not to "socially disturb" the somnolent low-I.Q. individual. He is charged with failure to give sufficient weight to drill and foundational mastery of tool materials and subject content. The educator, according to the querulous scientist, quite generally tends to glamorize techniques and devices instead of emphasizing major principles.

The university scientist (who usually is *not* certificated to teach in the public secondary schools of the state in which he lives) vociferously objects to such professional delinquencies, which are occasionally evident. His antipathy toward educational method is not lessened by the educator's pathogenic predilection for standardized objective true-false and multiple-choice examinations. The scientist is given to wondering about tests taken in punchboard fashion or marked with soft pencil between tiny optional spaces provided, with all question, debate, and discussion eliminated.[5] He is not certain of his own ability to differentiate between "validity" and "reliability," as a matter of fact. It is small wonder that he sometimes speaks and writes contemptuously of educators as "foes" of intelligent learning, holding much of today's educational psychology, sociology, and evaluation techniques to be pure "rubbish," "drivel," and "jargon."[6]

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[4] Herzog, Elizabeth G., and Sheatsley, Paul B., "Science Education as the Scientists See It," *The Educational Forum*, Vol. XII, No. 4, May, 1948.

Inertia

We all instinctively oppose what we do not at the moment comprehend, just as a little child gasps and cries when it is first lifted into the air by a stranger. This is only natural, for unless and until enlightenment is experienced in to what to the introversive mind of the university subject-matter specialist is an entirely foreign field, there can be little mutation of prejudiced viewpoint. "What was good enough for me is good enough for my children" continues to be paraphrased in antiquated but raucous clichés, for in spite of steady advances in scientific fields, there is resistance to steady advances in the field of education. The simmering disapproval of a few pedants, trained in the realism of empirical laboratory procedure and the idealism of pure research, to any and all educational method is perhaps understandable and to a degree unavoidable, in view of the environmental influences and life experiences (or lack of them) which have subtly molded and invaginated personal opinion throughout the years.[7]

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[5] The graduate record examination, series 37, required for admission to advanced study programs in many universities, requires *one and a half days* for completion, costs being borne by the student. Educational Testing Service, Los Angeles, Calif., and Princeton, N.J.

[6] Fuller, Harry J., "The Emperor's New Clothes, or Prius Dementat," *The Scientific Monthly*, Vol. LXXII, No. 1, January, 1951.

[7] Pediwell, J. Abner, *The Saber-tooth Curriculum*, McGraw-Hill Book Company, Inc., New York, 1939.

There is an obvious inertia as related to physical- and life-science departments in our institutions of higher learning tending toward maintenance of the *status quo*, which has in most universities been overcome only through the vigorous and stimulative quality of progressive thinking which spearheaded the broadened cultural education movement now so widely acclaimed.[8] This position is in a sense advantageous, for if the newer viewpoints of social outlook, course integration, idea interchange, community-industry cooperation, and general education are to survive, either in the university and college lower division or in our American secondary schools, they must do so on *merit*, demonstrated through acceptance among those who in the last analysis determine survival, the teaching body who contact the students and their problems.[9]

Support

Thoughtful leaders, on the other hand, dispel the tremulous fears of worrying colleagues and quiet the objections of those most articulate in defense of the "good old days," through expressed appreciation of the character-building virtues of cooperation in investigation, comprehension of issues and of statements, logical, coherent outgrowth sequence, and the social awareness inherent in the integrated program.[10] University committees are reexamining orientation courses in undergraduate science from the viewpoint of functional preparation for life *after* commencement, away from the enveloping shadows of the ivory-towered graduate school and the tenurial cocoon of the full professorship.[11]

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[8] Harvard University Faculty Committee, *General Education in a Free Society*, Harvard University Press, Cambridge, Mass., 1945.

[9] Cooper, Russell M., "The Rise of General Education," *NEA Journal*, Vol. 39, No. 1, January, 1950.

[10] Williams, Simon, and Laurits, James D., "Scientists and Education," *The Scientific Monthly*, Vol. LXXII, No. 5, May, 1951.

[11] Green, Elizabeth, "Student Evaluation of Teaching," *American Association of University Professors Bulletin*, Vol. 36, No. 2, Summer, 1950.

The trend toward social outlook in science is inexorable and nationwide. "We must not use the microscope until we spoil the eyes," says one writer.[12] Another [13] stresses the power of scientific minds turned to the problems of society, demonstrating the desirability of applying the rules of scientific method to social issues. That the principles of educational psychology have application here as elsewhere is evident in the gestaltic fusion of inorganic and organic chemistry into a configuration or whole body of chemical knowledge advocated for use in the secondary school class.

The United States Commissioner of Education, in a powerful plea for intensive interrelationship of science and society in our American secondary schools, has written as follows: [14]

> The sufferer in all this is the student-citizen and therefore society. As things now stand, he has a good chance of learning certain biological and physical "facts of life" about the world in which he lives. But his chances of understanding the impact those sciences have on our society and/or modify the effects of that impact, are all too often practically nil. . . . But the student cannot be expected to relate science and its method to the world about him unless the teacher of science is himself a student of relationships.

The science teacher-in-training thus finds himself in a unique professional position, swayed toward the straight and narrow path of subject delineation by a few of his science professors, yet urged to socialization of outlook in his education courses. To a much greater extent than is the case in any other teaching field, the science educator must evaluate the trend with a view to future plan of action. The student may indeed be inexperienced in actual educational practice, or he may be experienced as a secondary school instructor but interested in modernizing his thinking. In either case he is an adult and, as such, appreciates frankness and sincerity in orientation. In either case he weighs the evidence, evaluates motives, and makes his own decision.

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[12] Raymond, R. W., "The Requirements of Scientific Education," *The Scientific Monthly*, Vol. LXXI, No. 3, September, 1950.

[13] Murphy, Walter J., "The Scientist in the Social World," *Industrial and Engineering Chemistry*, Vol. 42, No. 1, January, 1950.

[14] McGrath, Earl James, "Science in General Education," *The Scientific Monthly*, Vol. LXXI, No. 2, August, 1950.

LEADERSHIP

It is the avowed purpose of the college professor of science education to effect a merger between the divergence of views expressed above, to bring about an osmosis of thinking between scientists steeped in dogmatic isolationism and the administrators, supervisors, and contact-experienced teachers of the secondary school. It is a function of this text in secondary science education to assist the undergraduate or the graduate in reasoning these parallels to an infinity of meeting in agreement on principles, to indicate the faults and the virtues of each, to demonstrate effective means of approach, and to point the way to a functional philosophy applicable to present and future *high school student* need. Science as a subject field offers application in but one phase of adolescent education, yet this facet of the secondary school curriculum provides latitude in socializing leadership.[15]

It will be the privilege of the young instructor graduating with training in physics and chemistry to bring new fire and enthusiasm into the secondary school laboratory. His service will contribute in enormous measure to the lives and life attitudes of those fortunate enough to experience his stimulative leadership. He will make certain that *his* charges have adequate background preparation in the manipulative techniques, skills, and mathematical problem solving requisite to mastery. The life-science man will remember that confusing statements are not confined to educators, for occasionally scientists err as well.[16] He will determine that those young people who go through his laboratory will have training in an analytical approach to problems, in experimental techniques, and in field observational backgrounds, plus a plainly indicated emphasis upon outline fundamentals of taxonomy, ecology, and the economics of living things.

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[15] Baker, Woolford B., "Science Teaching and the World of Tomorrow," *Science Education,* Vol. 34, No. 1, February, 1950.

Both physical- and life-science educators will blend emphasis upon subject content and scientific method with the concept of community-school-industry integration through experiment, demonstration, observation, discussion, and analysis, in a free spirit of democratic interchange. The best men will go far beyond strict subject limitations, concerning themselves with character development and citizenship training. Performance in terms of effective high school preparation for later life is the single criterion by which secondary teaching must be judged. Subject material, motivation, references used, and means of integration adopted must meet the tests of human understanding and personalized contact experiences, as well as those evaluating scientific accuracy.

With a firm background of subject training and an understanding of the type of opposition and degree of support to be expected,[17] there remains the problem of *correlation*. Having his objectives well in mind, the wise worker now looks about him to ascertain what finishing tools are at hand with which to ensure the probability of outstanding success in his chosen life career. It will be well to inculcate preparation in allied areas of concentration, for application of basic principles to specific problems is one of the keys to professional progress as well as to mental health and balance. Foremost among the correlative fields are *educational psychology*, *sociology*, and *philosophy*. These, of course, are extensive independent fields within themselves; only interpretative summaries are indicated in these pages, crystallizing pertinent phases specifically adaptable to secondary science education.

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[16] Lowenstein, Norman, "Biological Doubletalk," *School Science and Mathematics,* Vol. LI, No. 1, January, 1951.

[17] Garrett, Alfred B., "Science and the Liberal Arts," *The Journal of General Education,* Vol. III, No. 3, April, 1949.

PSYCHOLOGY

Environment

The character of surroundings has a great deal to do with student behavior in and out of school. As will be stressed in later chapters, the science instructor can provide stimuli conducive to learning through attention to physical aspects of his laboratory, just as the entire institution may be planned and administered with this end in view. Some classrooms fairly radiate a spirit of community effort and revelation in science, while others demonstrate a slothful sogginess in which otherwise capable instruction continually bogs down. Budget moneys and expensive equipment have very little to do with the subconscious appeal of mutual endeavor which the dynamic educator strives to create and maintain; much may be done with little if the drive is urgent and the significance of psychological appeal is realized and put to work by the classroom teacher.

Pride and loyalty toward the school which the adolescent attends and the classroom in which he studies science point the way to pride and loyalty behavior patterns with relation to the teacher himself and to the work done under his leadership. As the child emerges from the elementary school to new surroundings in junior and senior high school, he develops physically and matures psychologically as well. The change of attitude from compulsion to group loyalty and pride occurs simultaneously with the development of intellectual skills and knowledge, built upon previous experiences and subject to contact appreciation of the new school environment in which he spends the working day.

Home environment is also important, the attitude of parents toward education, which usually reflects the educational ceiling of the parents themselves, being of basic significance. In one home there is consistent support for P.T.A. activities and home-room projects, and one or both parents are present at school when such an invitation is extended. In such a home there is wholesome food and opportunity for rest, and church membership is exemplified. "Roll-up-the-rug-and-let's-dance" home parties for the young people and their friends are encouraged, and a generally congenial atmosphere is apparent, which includes sympathetic, dependable response to youthful problems.

In another house, perhaps on the same street and conducted on approximately the same economic plane, annoyance, ridicule, and flaring adult tempers greet requests for understanding help or cooperation. Religion is derided; sex is a subject for ribald humor. Excessive drinking, smoking, swearing, card playing, and adult carousing generally spawn like behavior in offspring, with resultant repercussions in the secondary school classroom. Environment is often coupled with heredity in these cases, nature and nurture simultaneously exerting influence.

Socioeconomic Status

The position of the family with regard to the community, a factor commonly associated with the amount of money possessed, is also a contributing influence in cases of maladjustment evident at school. Although some young people seem to be popular and accepted by classmates without reference to their social position, clothes, or pocket money, others are inhibited in their social contacts by real or fancied slights with relation to the economic level of their parents in the community. Money has a direct as well as an indirect application, furthermore, when provision for a quiet, well-lighted, clean, warm place in which to study or do home assignments in privacy is or is not possible of achievement, or when the adolescent has to work after school and on

Saturdays. The physical provision for comfort and peace in home surroundings may indeed have direct bearing upon the marks a youngster is getting in chemistry or physics. To have or not to have a little money to spend is also, at this age, of considerable psychological import, much social delinquence observed in our larger cities stemming from this simple factor.

Race and skin color affect social status in many of our school situations, this factor being more easily identified in some parts of the nation than in others. Here the science instructor enjoys a unique advantage in the universal unity of scientific purpose, which transcends national boundaries and language differences (except when forcibly restricted by international conflict) in search of truth. Much lasting intergroup good will is established through collective study of the scientific contributions made by men and women of other races than our own, the history of science being replete with illustrations which the alert educator may integrate. Albert Einstein is an American citizen today, but he was born, raised, and educated in Germany. George Washington Carver, the American Negro pioneer in applied chemistry, is a fine example. Guglielmo Marconi, Hideyo Noguchi, Wilhelm Conrad Roentgen, Elie Metchnikoff, and Vladimir Zworykin are other recent contributors through science to the progress and welfare of humanity. Going back but a little into the history of scientific endeavor, class research teams will discover that Alessandro Volta, André Ampère, and Georg Simon Ohm (the three investigators responsible for our electrical units of measurement—volt, ampere, and ohm) were Italian, French, and German, respectively. Anton Leeuwenhoek was a Dutchman; Gregor Mendel, an Austrian.

Mental and Physical Maturity

Mental ability tends to develop steadily, even in a normal environment, stability being shown with regard to the intellectual development of the adolescent.[18] Interests expand both qualitatively and quantitatively during the secondary school period, furthermore, giving ever-widening range to science instruction and increasing depth of comprehension potential from general science through senior physics.

Bodily growth and sexual maturity influence behavior to a marked degree, and the bearing of these factors upon action and reaction is most pronounced during the junior-senior high school period encompassed by this volume. Leadership is gradually acknowledged in the upper elementary grades as a direct result of physical stature and development, this condition broadening and deepening in influence during puberty. Those physically advanced assume control in both sexes; girls and boys of slower maturity attempt to compensate for their physical handicaps through tangential behavioral offshoots in order to attract attention or, through introversion, in order to avoid it. The significance of the physical maturation factor as it affects patterns in terms of "gang loyalty" among boys and "going with the right crowd" among girls will be analyzed at length in Chap. 3, General Science, under "Guidance."

Esprit de Corps

Mental health is as important to each young person in the science laboratory as it is to the teacher. Plan to watch for signs of inferiority complexes and unsocial behavior in your students, and if maladjustments appear give them careful analysis, including a discreet home survey. It is in this phase of "whole personality" maturation that the integrated science program excels, for the mutually constructive criticism, idea interchange, and research teamwork involved are unsurpassed as tools of psychological maturation. That most vital characteristic of harmonious group education, classroom morale, evolves from cooperative counsel as well as through watchful supervision; the need for discipline and control vanishes as community of confidence and progress results in adventure in learning.

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[18] Segel, David, "Intellectual Abilities in the Adolescent Period," *U.S. Office of Education Bulletin*, 1948, No. 6, Federal Security Agency, Washington 25, D.C.

Learning

What should the science man know about learning? Perhaps the first thing to realize is that it is an extremely complicated process! Learning involves not only the personal and social characteristics of those who learn, but the type of environment involved and the form and extent of the material to be learned. The interested educator has recourse to abundant and excellent sources available in the field,[10] hence elaboration here is neither intended nor justifiable. It may be well, however, to summarize with brevity some of the more applicable psychological factors involved in secondary science education.

Drill is a factor in learning; we know that repetition aids in fixation. Of course, there is nothing new in this, for drill is perhaps the oldest of techniques. *Intensity of concentration* is also important, for if a fact or a thought is repeated often enough and strongly enough there is a good probability of retention. We all "know by heart" some few phrases or one or two poems learned in early childhood, for instance, which have resulted in lifetime tenure, and often adults concentrate on repeating verbatim a selection from Shakespeare which has impressed them. "Forgetting" enters the picture here, for we forget vastly more than we remember unless we recall and repeat with emphasis the fact or phrase once ingrained in a recess of the mind. Forgetting results not only from the interference of new learnings

[10] For example, Sorenson, Herbert, *Psychology in Education*, McGraw-Hill Book Company, Inc., New York, 1948; and Beaumont, Henry, and Macomber, Freeman G., *Psychological Factors in Education*, McGraw-Hill Book Company, Inc., New York, 1949. See also Sands, Lester B., *An Introduction to Teaching in Secondary Schools*, Chap. XI, "Using Psychology in Education," Harper & Brothers, New York, 1949.

which intrude upon the recall, but from lack of use of behaviors. This is the principle of *use and disuse*, governing such recurring lifetime memories as "Twinkle, twinkle, little star," or "Now I lay me down to sleep." Until the invention and perfection of a mechanically scientific device such as an "automatic electronic library,"[20] we and our students must repeat and concentrate constantly in order to remember what we have learned over a period of time.

Another factor in learning is the comparative *recentness* of recall. How long has it been since the statement or phrase was last repeated? Other conditions being equal, the more recent the use, the easier the recall. Every college student is familiar with this principle; if one goes over the chapter just before entering the examination room, the picture remains clear for a time, which is one phase of long-range retention.

The principle of *effect* has bearing upon the integrated science program. Young people learn when they are interested. They become interested partly because everyone else in the laboratory (including the teacher) is interested, for social enthusiasm is not only effective but highly contagious as well. The process of learning through mutual effort and cooperative sharing of results is pleasant and obviously beneficial; the pleasant sensations are retained, and so are the science lessons associated with them. Affective or feeling states have reciprocal actions, learning being influenced by interest as well as by environment, and vice versa.

"Nothing succeeds like success" is an adult maxim which has bearing upon the learning process. Hence, if failure is lessened, or if the reasons for it are noted and shared by the socialized group, even failure loses its sting in the resolve to do a better job and watch the techniques next time! Emotions influence attitude toward science as toward any subject in the curriculum, and mutual association to rule out error and to further the probability of successful progress is of paramount significance in effect psychology.

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[20] Walker, Fred L., "Blueprint for Knowledge," *The Scientific Monthly,* Vol. LXXII, No. 2, February, 1951.

Desire or wish to learn is perhaps the most potent among all learning factors. This is variously referred to as "interest," "will to try," "readiness," or "mental set," and refers to the drive behind the individual's study. Mental set implies learning with a purpose, and has been found to have a high retention quotient at all grade levels up to and including the doctoral oral and written examinations culminating the graduate school. "One never really learns a subject until one is called upon to teach it" is a well-worn professional cliché, and one with which the young teacher-in-training will be in hearty accord as he enters upon field practice! Here again the integrated science program holds a decided advantage over the "You teach 'em social science; I'll teach 'em botany" school of pedagogy, for integration with life means appeal to personal problems and objectives, keys to interest and will to learn.

The Socialized Classroom

High school science courses will contribute directly to the solving of youth's problems in the modern scheme of administrative supervision, and of all the known devices which further this aim nothing is more effective than the socialized classroom. If provision is made for student participation in selecting group objectives and in the working out of optimum procedures, course content will mold itself to the pattern of student need.[21] In situations where the adolescent himself has a part in discussion, there is high probability that goals will be better defined in terms of attainment and suitability than where the teacher arbitrarily lays out the course from the science-content viewpoint alone. The teacher supplies the overview of subject knowledge; students discuss their own needs in terms of science problems and experiments, the course thus contributing to the emotional, social, and intellectual maturation of those enrolled.[22] Guiding the learner in successful experiences which will produce desired behavior, through cooperative discussions and periodic evaluation in terms of self-set objectives, is the ideal.[23]

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[21] Reid, Chandos, "Instructional Materials and Problem-centered Teaching," *Teachers College Record*, Vol. 52, No. 1, October, 1950.

SOCIOLOGY

Orientation

The relationship of science education to society on the one hand and to immature young people on the other presents a perennial professional problem.[24] Educational sociology, like science education, is comparatively recent as a special field, the first textbook bearing such a title having been published in 1917. Much of educational psychology and human biology is utilized by sociologists in relating what is known concerning the mechanics of learning, child maturation, genetics, and eugenics to the interests of society. The primary concern of this important field of concentration as it is applied to the disciplines involved in science education will be the orientation of boys and girls to the great body of scientific theories, doctrines, and facts. Allied objectives will be to convey an appreciation of the motives associated with pure and applied research, to survey the contribution potential of invention and discovery in terms of social evolution, and to give thorough training in inductive methods of scientific approach. Attainment of these objectives will further child-science-life orientation.

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[22] Anderson, G. Lester, "What the Psychology of Learning Has to Contribute to the Education of the Teacher," *The Journal of Education Psychology,* Vol. 41, No. 6, October, 1950.

[23] Schonell, F. J., "New Concepts in Education," *The Educational Forum,* Vol. XV, No. 2, January, 1951.

[24] For complete coverage, see Cook, Lloyd A., and Cook, Elaine F., *A Sociological Approach to Education,* McGraw-Hill Book Company, Inc., New York, 1950.

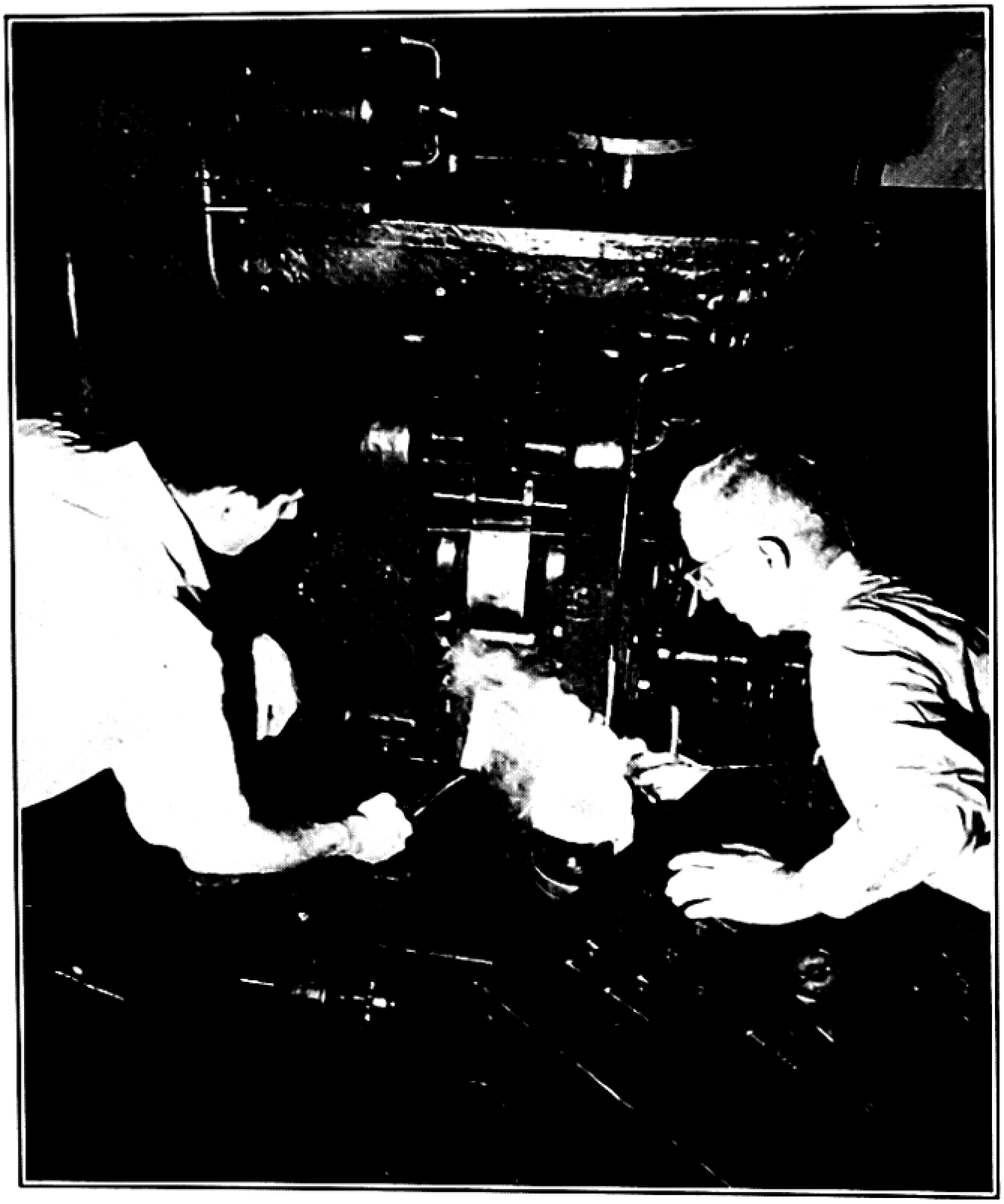

FIG. 1. The interrelationship between scientific research and industry is exemplified in the development of a new cold treatment which superhardens stainless steel. The strip of metal has been immersed in a foaming flask of liquid nitrogen, with a temperature of 300 degrees below zero Fahrenheit. When rolled and later heat-treated, the steel will be three times harder than any previously known. (*Photograph courtesy of the Westinghouse Electric & Manufacturing Company.*)

Social Change

It is of importance that we realize at the outset a peculiar quality of society, if we are to undertake even a brief analysis of means of preparing high school students for functional positions with relation to it. This is the quality of *change*, a state of continual evolutionary flux which characterizes life and living with relation to personal relationships, to the local community, and to national and world events.

The university or college concerned with preparation of leaders in society will recognize this shifting panorama and will develop its curriculum in terms of general education for citizenship.[25] The junior-senior high school curriculum (embodying courses in the sciences) will be coordinated in similar fashion—administrators, supervisors, and classroom teachers mutually cooperating in recognition of the over-all objective.[26]

The Role of Science Educators

To bring democratic social living within the sphere of the school is a major aim of all concerned. Science teachers are not isolated in this regard; rather the opposite, their place is in the vanguard of social understanding because of the vital immediate impact and future potential of their subject fields in terms of society. No one today puts on clothes, cleans the rugs, washes the dishes, polishes the car, sits in a chair, reads a book, listens to the radio, answers the telephone, watches a television program, eats, drinks, or even breathes (!) in heated or air-conditioned rooms without undergoing direct science-life experiences, for science today has application to everything we contact in civilization.

To bring science to bear on society along the frontier of education, and to bring society to bear on science and its students through broadened community-industry interchange must be the essential motives.[27] If democracy is to function nationally, breadth of concept and understanding must be spread through the youth of the country, for the power of the ballot box and representative government depend upon social action and reaction. The factual background and method of intelligent analysis furnished through

[25] Hutchins, Robert M., "The College and the Needs of Society," *The Journal of General Education*, Vol. III, No. 3, April, 1949.

[26] Hand, Harold, "Local Studies Lead to Curriculum Change," *Educational Leadership*, Vol. VIII, No. 4, January, 1951.

[27] Russell, Bertrand, *The Impact of Science on Society*, Columbia University Press, New York, 1951.

studies in both physical and life sciences hold a most prominent place in social education today, with constant application both in peacetime living and in wartime survival.

The Activity Program

Building upon the recognized success of socializing techniques in the elementary division, formalized secondary school instruction in all subjects is undergoing a national metamorphosis toward an informality of approach. While accenting social intercourse and group-work problems, secondary instructors planning activity programs will studiously avoid the laxity in over-all classroom control, drill, and mastery which in many instances characterized the early experiences of elementary school teachers entirely unfamiliar with, and untrained in, activity administration.[28] Group-participation programs at the secondary school level, while controlled and guided by instructors, are permissive of far greater latitude in participation and planning by the relatively mature students of the high school environment. In discussing their own needs, interests, and goals, students uniformly appreciate this cooperative approach and are happy in group participation. In terms of effect psychology, lessons learned and methods of investigation derived through such activity work are of definite and lasting merit.

In some high schools the activity period is separate and distinct, being either followed or preceded by "regular academic" classes.[29] In other institutions, activities are merged with the academic-content subjects, such as the various sciences. The latter, in the author's opinion, is infinitely preferable, provided that science teachers are available who have breadth and depth of social training that enable them to participate in such a student-centered program. Provocative stimulation of such an outlook is one purpose of the present text in science educational method.

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[28] Wells, Harrington, *Elementary Science Education,* Chap. 2, "Trends and Methods," McGraw-Hill Book Company, Inc., New York, 1951.

[29] Flaum, Laurence S., "The Creative Activity Program for Secondary Schools," *The Educational Forum,* Vol. XV, No. 1, November, 1950.

In practice, secondary school procedure does not alter the integrated activity program of the elementary school, with which most students today are becoming quite familiar —a decided point in its favor. "Units," however, are not normally carried on in terms of extended school-day time areas, the departmental plan of the high school rendering such work continuity impractical except in cases where there is mutual agreement on core-unit correlation between subject field specialists. In the secondary school the core consists of separate subjects encompassing interests and objectives of all students, science and consumer education being prominent in the sequence, closely allied with English and the social studies.

Activities in the secondary school take the form of periods devoted to "group dynamics," discussion of problems and mutual evaluation of techniques being conducted on a guided student-participation level.[30] Science informational deficiencies and needs of the many individuals in the group are openly discussed, being channeled into a few common areas of mutual interest and experimental concern in open class forum. Where conscious effort at socialization is carried on by instructors genuinely interested in the welfare and progress of young people, students may be led to distinguish process from content in science, the way being opened for social maturation as well as for indoctrination with the ideals and methods of inductive reasoning which feature science education.

Girls and Society

Girls as well as boys enter fully into activity planning, often exerting strong leadership, as a matter of fact. Female docility is socially passé in America, for under current conditions of adult life women who choose to do so may drink in public, smoke in public, or argue in public. Women hold journeyman membership cards in labor unions, serve in defense factories as well as in the armed forces, become professional teachers, nurses, laboratory technicians, surgeons, dentists, and attorneys at law. Women not only drive city buses and clean city streets; they actively enter politics to become mayors of cities, Representatives in Congress, and United States Senators.

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[30] Hanson, John W., "A High School Experiment," *Educational Leadership*, Vol. VI, No. 4, January, 1949.

Women raise families, vote, belong to service clubs and civic organizations, listen to radio commentators, watch television programs, and become commentators and "video" actresses themselves. Women occupy high places in business and industry, laying out plans, designing future trends, and allocating funds for work activities followed by men. Housewives control most of the country's purchasing power, and we know that there are more girls than boys in our high schools today. Females statistically outlive males by approximately eight years, and women inherit practically all of the nation's wealth. According to the national census of 1950, the "average American" is a woman. Social thinkers used to joke about "women wearing the trousers" in the family unit. It is no longer a joke, if social thinkers think.[31]

Community-School Coordination

Science education is in positive agreement with the concept of community coordination. Field trips to points of interest pertinent to the course of study were in vogue long before their analysis with respect to the integrated program, and reference to field observation is indicated throughout the chapters devoted to the specialized sciences which follow. Observation and participation as contributory experiences are as desirable in the classroom laboratory and in the commercial factory as they are along the edge of an inland creek or marsh and among the fascinating tide pools revealed at ocean's low tide.

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[31] Wells, Harrington, "Social Problems in Post-war Science Education," *Sierra Educational News*, Vol. 42, No. 4, April, 1946.

Projects in biology, botany, zoology, chemistry, and physics may readily be coordinated with community offerings in these science fields, and "general science" naturally mingles with the local environment in almost every phase of its widespread interests. Theater ventilation, prevention of colds, cancer campaigns, conservation programs, "swat-the-first-fly" slogans, and rodent-elimination crusades are examples of socialized community-school activities participated in by senior high school students. The total resources of the community will in like manner be held at the disposal of the school, not only in the persons of administrators, supervisors, and visiting speakers, but through the enlisted cooperation of physicians, druggists, recreation directors, farm advisers, engineers, and others representative of the local environment who may contribute to the social awareness of science students.

PHILOSOPHY

The American secondary school is an eclectic institution in which many viewpoints are merged or exist concurrently in homogeneous harmony under wise and resilient administration beneath the same roof. Educators of varied ancestry, religion, and political party affiliation exchange views and parry antagonists in that great melting pot of the profession, the faculty or staff meeting. A multitude of young people from widely differing home environments stream through entrance doors and down long corridors to their classrooms each working day. All are admitted and instructed without tuition charge by members of the faculty, and all have equal opportunity in laboratory, recitation, and examination periods to move forward toward achievement of their chosen goals. This is democracy in practice, and the United States is the only country on earth where such idealism is actually functioning realistically in an open, free society.

A hypothetical situation will provide an overview of essential viewpoints in educational philosophy. Let us assume that three young science teachers are walking along a city street on their way to a lecture scheduled for eight o'clock in the evening. As they leisurely stroll, after a pleasant dinner, they suddenly wonder how much time they have and find, upon mutual inquiry, that only one of them has remembered to wear his wrist watch. According to the owner of the watch, they have plenty of time, for the lecture is at eight and the watch reads seven o'clock. Just then the three teachers pass a grocery store which has a large clock on the wall, and glancing through the window they note that the store clock indicates exactly seven. "That settles it," says the young man with the watch. "Both say seven o'clock; we have plenty of time."

The teacher walking in the middle is apparently not worried in the least. "What do we care?" he asks. "Suppose we don't arrive at the university in time? We could walk around the campus a little. I love the campus at night; it is so peaceful and quiet, one can almost capture the spirit of learning itself as one watches the little lights glowing in all the study rooms. Perhaps the chapel is open, and if we miss the lecture we could stop there for a while. There will be other lectures!"

The third young scientist, who secretly wishes he had worn his own watch, which he frequently checks with Western Union time for accuracy, is quite disturbed by the complacency of the other two. "How do we know that the old store clock and your wrist watch are right?" he asks. "I think we should look around; perhaps we might find one or two other clocks. Or we might listen for a radio time signal. Perhaps we should stop and telephone some place where the time is accurate, then we would know just what time it is and how fast we will have to walk."

Each of the young science educators represents a basic viewpoint in philosophy. We should pause to examine each if we are to understand ourselves, which is the first step we must take in orienting our own behavior with relation to our fellow citizens in the community, our professional associates, and the students we contact in our classes. Like psychology and sociology, the field of philosophy is of great depth and breadth of concept, and our survey of applicable tenets as related to science education will serve its purpose if it points the way to further investigation.

Realism

From a realistic viewpoint the science teacher is part of the educational equipment of the institution which pays his salary. He resembles in both inward reactions and attitudes as well as in professional demeanor the walls, blackboards, aquaria, chalk, and flower pots among which he works. In the laboratory he demonstrates with precision and a certain prim finesse; in the lecture hall he orates mechanically, physically, giving neither excessive weight nor undue lack of emphasis to each phrase and act. The facts he presents are so; he knows that they are so, and he feels it his duty to impress upon his hearers the authenticity he reveres.

The compendium of science which the realist has at his command is cold in the sense of positivism and is irrefutable except upon presentation of impeccable experimental and statistical evidence, confirmed in accepted, responsible quarters and subjected to proper qualitative and quantitative controls. The soldier in a foxhole is a realist; he knows that his physical survival depends upon his reactions to environment in terms of "kill or be killed; fall flat on your face in the mud or be riddled with machine-gun bullets." Realism is stark truth, positive and physical.

Idealism

The idealist is most happy when thoughtfully dreaming. There is no taint of practical financial reward associated with the pure research of the idealistic educator. He cares little that others think him impractical, including his wife, who has learned to make allowances for tardiness and procrastination as well as for occasional unkempt appearance. He ignores the fact that he has a hole in the sole of one shoe, that his house is small, that it is raining outside, that his students are few in number. His reality is deeper and more spiritual in quality, transcending physical environment. The idealist believes implicitly in the collegiate honor code and in the principle of moral rearmament. He holds to the idea of passive resistance, a "turn-the-other-cheek" philosophy; there *is* honor among thieves.

An element of *mysticism* is involved in idealism. The mystic ignores time. He knows that the "seven o'clock" indicated by the wrist watch of the realist does not mean what it says. The watch is a mechanical, physical, lifeless thing, without being; it does not know any better. It may be seven o'clock by Western Union or radio time in New York, but it is six o'clock in Chicago, five o'clock in Salt Lake City, and only four o'clock in San Francisco. In Korea it is not even today; it is tomorrow! It will all be the same, in a hundred years, whether the three science teachers attend the university lecture or not. Or it may not be the same, for if they do attend, one of them may get an idea which may revolutionize the civilization of the world. But is the world so important? There are other worlds, and billions of other suns, about which we know so very little. It is all part of a great developmental plan, and our part in the eternity of the cosmos is small indeed. We should not fret over trifles, for there are great truths to learn in reverence and humility.

In the high school laboratory the idealist ignores the profanity crudely penciled on the smooth inner surfaces of his zoological clamshell specimens. He lifts himself above the flying erasers and bits of chalk which fill the air during his home-room period. His students never quite get around to finishing their assignments, which were probably too long anyway, so he excuses them patiently. The idealist, however, gives approval to the integrated science program; in fact, he thinks there should be a great deal more activity work and social correlation. He approves of field excursions, too. He really loves his work, his associates, and every one of his students, good and bad. It is a paradox (which often confounds realistic administrators) that in a surprising number of instances even the worst behavior problems in the school come to love him too.

Pragmatism

The pragmatist believes in "learning by doing." He holds to the experimental problem method of approach, and his reactions are biological and social rather than physical. The pragmatist is an ecologist and a physiologist as well as a geologist and meteorologist; he is a biochemist as well as a nuclear physicist. He studies environment, both biological and social, orienting physical factors in the process, especially with reference to the reactions of organisms, including man. The pragmatist, then, approves of the activity program and the integrated laboratory as he does all forms of social and environmental experimentism. He respects the purposes, measurements, and behavior studies of the sociologist and the psychologist; he appreciates the experimental efforts in striving toward perfection of educational administrators, and he therefore makes an enthusiastic and cooperative staff member, the dream of departmental chairmen everywhere.

Fact is fact. Water boils, evaporates, condenses, freezes, melts, and flows. Students know or they do not know; the high school science teacher knows this, and he knows that he knows it. The man of science will be the first to admit, however, that fact may be changed upon submission of proper evidence. New discovery often negates prior knowledge. In the chapter which follows we shall review the circumstances resulting in new chemical element discoveries, and the dramatic surmounting of the sonic speed barrier. Today we teach, upon the basis of present knowledge, that the only cures for malignant tumors are early radiation from radium or X ray, or prompt surgical excision. Tomorrow may change our information and our teaching. Prior to January, 1930, all general science teachers gave instruction in the orbits of eight planets revolving about our sun. Lowell Observatory at Flagstaff, Arizona, changed the facts and hence the teaching of planetary astronomy throughout the world with the discovery of the planet Pluto.

Summary

Scientific knowledge of fact is temporized by the pure and applied experimentalism of science itself. Experience teaches the virtue of a generally pragmatic approach, while idealism is held in reserve throughout all secondary teaching in terms of ethics, human values, and ultimates. As a realist, moreover, the science educator views philosophical search for truth as a demonstration of the analytical problem approach, aiding in the training of young people for life through providing insight into life's practical problems. Philosophy is thus seen to be a science in itself, applying the principles of the scientific method.[32] The science educator would not be a realist if he failed to take idealism and pragmatism into account. He would not be an educator if he were not at heart an idealist. He would not believe in experience, experiment, and proof if he were not a pragmatist. Science and the scientific method thus imply integration of idealism, realism, and pragmatism in philosophy.

PROBLEMS FOR GROUP DISCUSSION AND REVIEW

1. Discuss the relationship between science and society.
2. What objections are advanced by critics of educational method? To what extent are these valid?
3. How is the inertia tending to a maintenance of the

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[32] Reichenbach, Hans, *The Rise of Scientific Philosophy*, University of California Press, Berkeley, 1951.

status quo being overcome in our teacher-training institutions?

4. In what ways is the general education program of our colleges contributory to a well-rounded teacher-preparation curriculum?
5. Outline the strategic position occupied by the college science teacher-in-training with reference to current educational trends.
6. Describe the role of professional leadership in terms of objectives in physical- and life-science education.
7. Present some of the outstanding contributions of educational psychology to the new field of secondary science education.
8. What do we know about learning? How does the learner learn?
9. In what ways will the modern science educator integrate school, industry, the community, the nation, and the world?
10. Discuss realism, idealism, and pragmatism as applicable to teaching science in the junior-senior high school.

Chapter 2. SCIENCE AND THE SCIENTIFIC METHOD

In evaluating the contributions of science and scientific training to the physical, mental, and moral maturation of secondary school students, we must bear in mind the fact that the great majority of those enrolled will not themselves become professional scientists. It is in the realm of social awareness that integrated science education exerts its greatest influence, for much of the life and work of the high school teacher will be spent in enlightening the "average" young people in his classes (the rank and file of parents, consumers, critics, and voters of tomorrow) in terms of attitude, judgment, and appreciation.

Teacher Objectives

Analytical investigation is essential as a function of democratic government today at all levels, from the community to the Congress, for it is the collective will of the people which determines local and national stagnation or progress. Intelligent discussion, open-minded reception of conflicting ideas, and constructive criticism constitute the collective voice and power of citizenship. These may embody comprehension of principles involved in the establishment of a rural conservation district, as well as those affecting national decisions relating to bacteriological warfare, maintenance of radar outposts, or the products of nuclear fission. The collective judgment of an informed citizenry is the basis of democratic government. That the judgment of the educated majority shall be influenced by demonstrable fact and experimental evidence is an objective in the sequence of science education in the secondary school.

Government stockpiling of scientific manpower is as important as the accumulation of critical physical materials, in the interest of individual and national survival. Leadership in all forms of competitive endeavor is dependent upon research and new developments.[1] In a period when combat planes, for example, become technically obsolete within months after they have been test-flown, America is socially dependent upon scientists for future protection and progress. The secondary school science teacher serves democracy and preserves the democratic way of life as he integrates science with the humanities, schooling all the members of his classes in the inherent worth of science and the scientific method.

It must not be forgotten, however, that the embryonic scientist—the future Ph.D. and research specialist—also listens, watches, works, and learns among his fellows in the high school laboratory. It is as much the privilege of the science teacher to motivate his individual leadership and promote his technical experimentation, while providing for sturdy competence, as it is a professional duty to carry the entire class forward in group mastery and social orientation. The high school teacher is an *interpreter* of science, adapting content, sequence, method of investigation, socializing activity, and laboratory procedure to the training of student masses as well as talented individuals in our American democratic environment. Integrated education, including extracurricular activities, gives opportunity for segregation and encouragement of those science students with career leadership potential.[2] As the frontiers of science are pushed forward, the science educator will coordinate the *scope,*

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[1] Stakman, E. C., "Science and Human Affairs," *Science,* Vol. 113, No. 2928, Feb. 9, 1951.

[2] Coutant, Madeleine F., "Youth for the Scientific Frontier," *The Educational Focus,* Vol. XXI, No. 2, October, 1950.

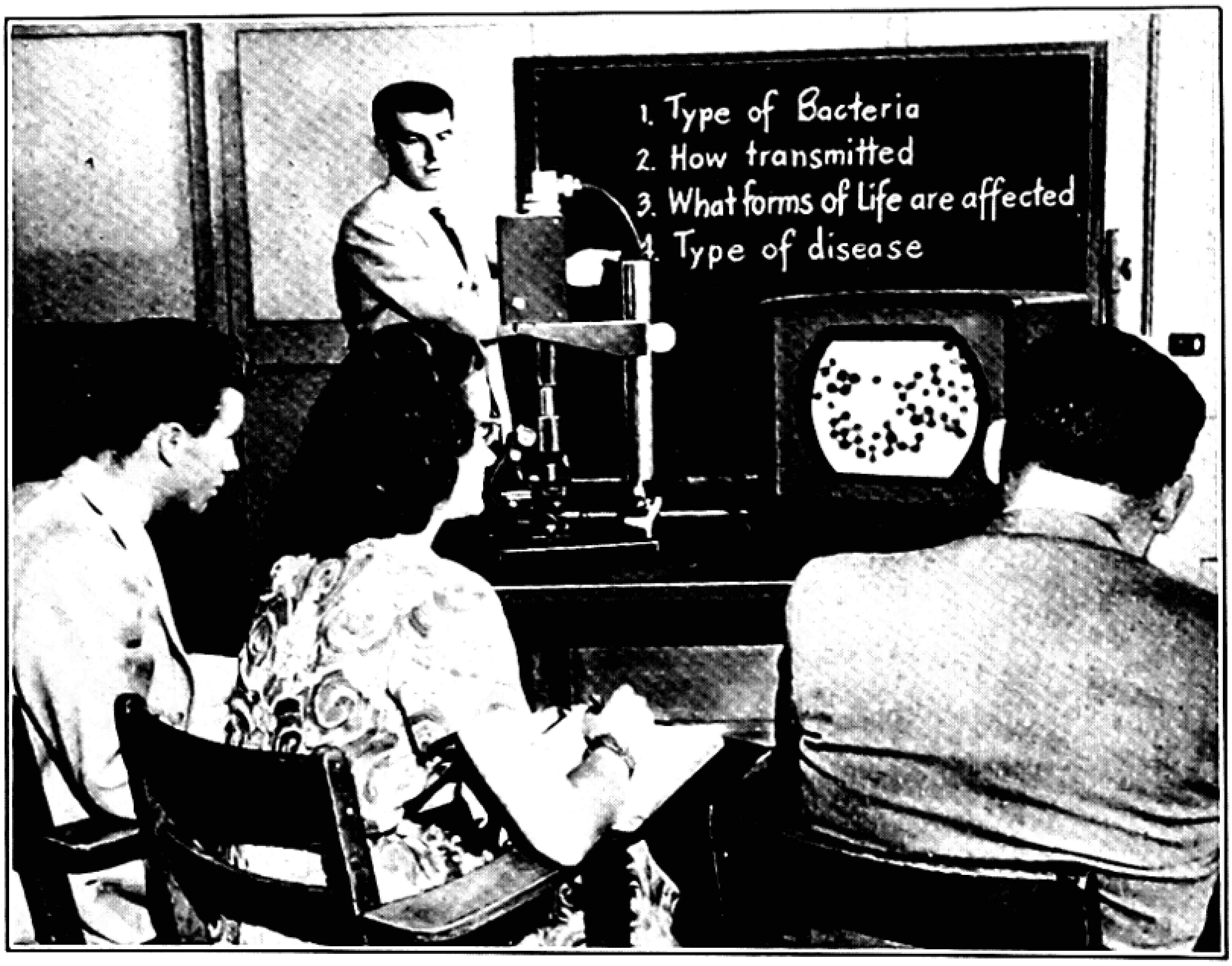

FIG. 2. A teacher-training student demonstration in interpretation through the use of modern equipment. When a miniature television camera is trained on the eyepiece of a light microscope, the entire class is enabled to view the enlarged microscopic field on the receiver screen. (*Photograph courtesy of the RCA Victor Division, Radio Corporation of America.*)

perspective, and *method* of science with relation to present and future student needs.

THE SCOPE OF SCIENCE

What Is Science?

Concepts of meanings involved in science vary in accordance with viewpoints of individuals, for science means many things to many people.[3] A succinct definition is impractical, inadequate, and inaccurate, hence we must rely upon the Platonic method in defining an abstraction in terms of concrete illustrations. To some, science means knowledge, tested, controlled, and authoritatively approved. To others, it connotes freedom of inquiry and limitless discussion of ideas. Some scientists put their faith in stimulative curiosity, reasoning, and logic, leading to establishment of effective methods of formulating concepts and testing postulations.

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[3] Johnson, Philip G., "The Meanings of Science," *The Science Teacher*, Vol. XVII, No. 4, November, 1950.

Science to many implies nurture over nature; ethics, standards, and reverence instead of blatant shouts and claims, irresponsibility, and carelessness. Science means keeping abreast of contemporary writing, not alone in a field of specialization, but in allied fields as well. It involves continuous evaluation and reevaluation of ideas or hypotheses in light of continuous new knowledge and experimental evidence. Science progressively evolves through freedom of international exchange, in a mutually cooperative search for factual truth.[4] Science ignores skin color, sectionalism, nationality, and language variance as it ceaselessly matures through the interdependence of science itself. Science is Armageddon and altruistic salvation, for science is the hope of mankind today.

Physical and Life Science

In educational circles it has long been customary to distinguish between physical sciences, such as chemistry or physics, and the "life" sciences devoted to various branches of biology. From the practical viewpoints of high school teacher preparation and employment the distinction is still quite valid, for each secondary divisional field is specialized in skills as well as in content. Institutions of higher education concerned with the production and certification of competent teaching personnel are often segregated into departments or schools of botany, zoology, geology, physiology, chemistry, or physics, each with lovingly inherited and jealously guarded subject areas and frontier boundaries.

[4] Smyth, H. D., "The Place of Science in a Free Society," *American Scientist,* Vol. 38, No. 3, July, 1950.

Science in the modern sense draws no fine lines of demarcation between separate fields of concentration. On the contrary, there is a true trend toward intercommunication and integration with relation to professional training of all types, not alone in terms of general education [5] and socialization of outlook, but within the sacrosanct confines of our schools of physical and biological sciences. Biochemistry, physical chemistry, chemical thermodynamics, quantum chemistry, mathematical biology, geochemistry, photochemistry, geophysics, electrobiology, biogeography, paleobotany, and photobiology illustrate the crossing of traditional boundary lines in the mutual sharing of skills, knowledge, and techniques.[6] The age of science [7] may truly be characterized by the maturation of a spirit of factual interchange and mutual respect between the disciplines. The prime objective of all science has been and will continue to be the discovery and confirmation of new knowledge, the establishment of general laws or truths.

Implications of this interdenominational harmony within the confines of science are beginning to make their presence known in secondary teacher training and will have marked effect with regard to placement and professional advancement in the future. Many of our best candidates "major" in one general field and "minor" in the other, thus obtaining an interlocking background facilitating factual interplay in professional presentations and in stimulating student investigations. Through the discipleship of science education, interdepartmental training will aid in the maturation of young people through orientation and social correlation,[8] as will be indicated in the treatment of specialized fields throughout this book.

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[5] Faculty of the College of the University of Chicago, *The Idea and Practice of General Education,* University of Chicago Press, Chicago, 1950.

[6] As an example of interplay between physics, chemistry, mineralogy, and geology, see Muench, O. B., "Determining Geologic Age from Radioactivity," *The Scientific Monthly,* Vol. LXXI, No. 5, November, 1950.

[7] Oppenheimer, J. R., "The Age of Science: 1900–1950," *Scientific American,* Vol. 183, No. 3, September, 1950.

The tremendous potential existent in ocean water with relation to raw materials provides an interesting example of biophysical intercorrelation on a science frontier. Biologists, chemists, physicists, and physical geographers present various facets of the problem, of interest to educators in motivating discussions and inaugurating group activities. The mechanics involved in attempts to harness tidal power, various schemes proposed for making fresh water from sea water (and what would happen to the Saharan, Arabian, and southwestern American deserts if this were successful at reasonable cost), mysteries surrounding the migration routes of some important fishes, and the availability of biological food sources provide pertinent topics. Preparation of edible substances from limitless plant material rich in iodine, calcium, and potassium awaits further investigation by biochemists and algologists. Oceanographers and physical chemists agree that there are 90 million tons of chlorine and 53 million tons of sodium in each cubic mile of sea water. Utilization of this vast and virtually untapped natural resource is one of the future problems of biological and physical science. Discussions and socialized activities related to this and similar frontiers will bring into focus varied informational material from many sources, providing excellent training in fact assemblage, hypothesis formulation, presentation, analysis, manipulation of controls, and logical reasoning. Encouragement of youthful scholars to draw upon *all* available sources, employing the elements of logic with reference to interpretation, is both ideal and practical. Integration is the essence of progressive educational philosophy.[9]

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[8] Solomon, Marvin D., and Braunschneider, G. Edward, "Relation of Biological Science to the Social Attitudes," *Science Education*, Vol. 34, No. 2, March, 1950.

[9] Yancey, P. H., "Science and Education," *Bios*, Vol. XXI, No. 2, May, 1950.

Pure and Applied Science

"Pure" science is interested in idealistic truth. Any commercial uses to which discovered facts or laws may be put by industry are of little import in the pure-research laboratory, as are any possible pecuniary rewards which might be forthcoming in consequence of research endeavor. A zoologist of the highest intelligence will spend a decade in working and reworking the taxonomy of world holothurian echinoderms, for example, and will be surprised, disconcerted, and to a degree insulted by any expression of its "uselessness" upon the part of a lay observer. To the pure scientist, any contribution to the sum total of human knowledge, no matter how irrelevant it may appear to be, is eminently worth while. Investigation for the sake of investigation, science for science, is the ideal.

"Applied" science, on the other hand, is realistic in philosophy, being interested, among other things, in finding possible practical adaptations for the experimental results of pure science. The commercial development of penicillin from an obscure mold, *Penicillium notatum*, after the bacteriostatic effect had been noted in pure research some years before, is a classic example of applied adaptation. It was not until fifteen years after Alexander Fleming made the original observations that this potent enemy of death was clinically proved and commercially produced.

During recent years there has been a marked trend toward intentional, direct application of technical knowledge and skilled personnel to the cogent problems of society, through the cooperation, facilities, and financial interest of industry. Chemists, biologists, and physicists experiment "on the payroll," partly with the betterment of humanity in mind, but immediately in terms of commercial corporation control of new, desirable, infinitely better products. The chemurgy of cellophane from plant cellulose and of artificial leather from cottonseed oil illustrate this economically dominant viewpoint. Many scientists work for the government in similar fashion, applying the techniques of science to technological advancement of the nation in the continuous race for economic and military control.

Philosophy, ethics, and logic are involved in any comparative discussion of the relative merits of pure and applied science, for no man can say in truth that industrial progress is not ideally beneficial to mankind. The commercial synthesis of camphor from turpentine and the production of synthetic rubber from acetylene, prior to the Second World War, by chemical engineers of E. I. du Pont de Nemours & Company, Inc., together with Monsanto Chemical Company's electric-furnace production of phosphorus and Dow Chemical Company's process for extracting magnesium from sea water are potent examples. Synthetic rubber and ata-

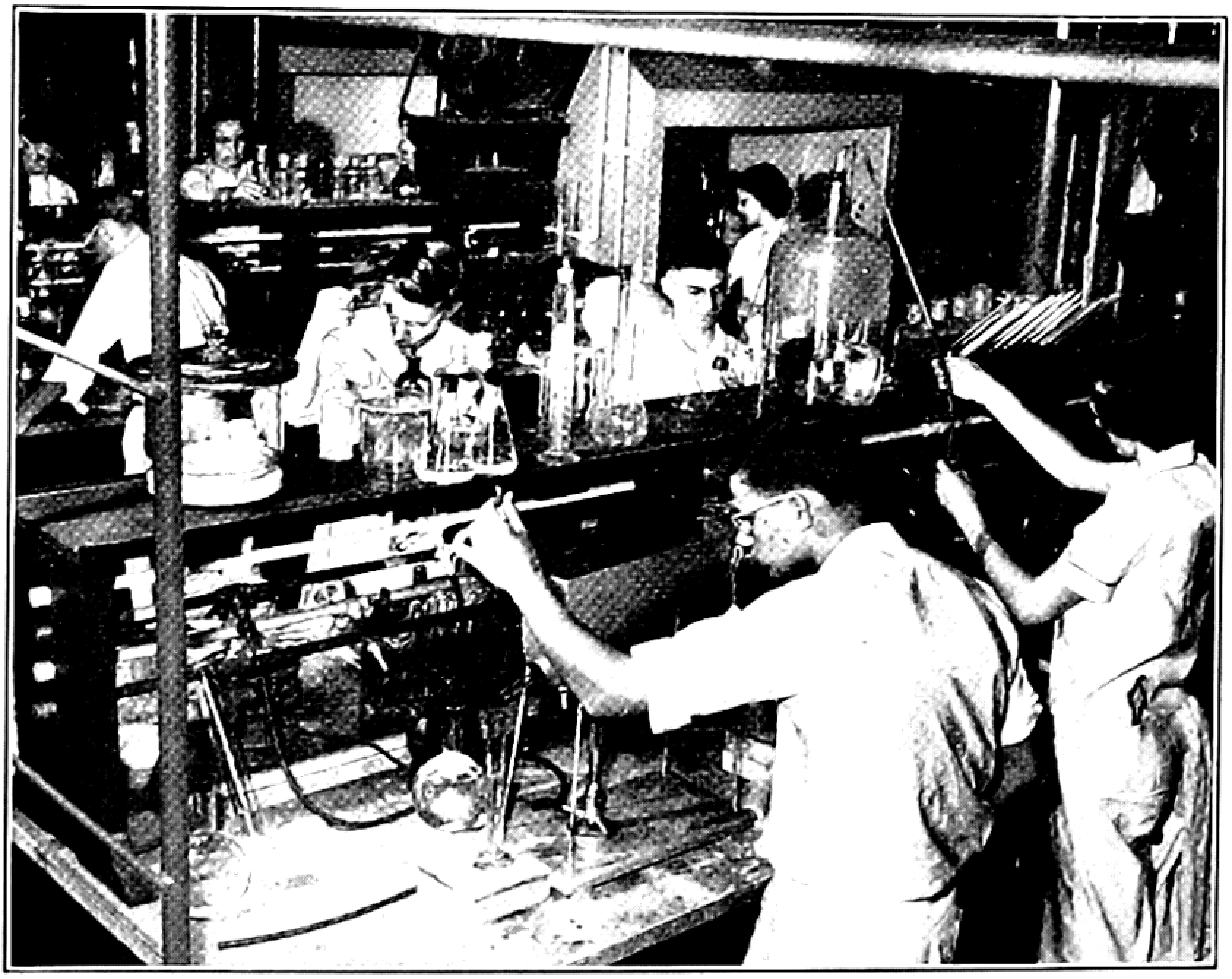

FIG. 3. Science-industry cooperation in actual practice. These high school science students have just graduated and are on the payroll while engaged in intensive postgraduate technical training preparatory to industrial assignment. (*Photograph courtesy of the Monsanto Chemical Company.*)

brine may be said, without fear of contradiction, to have made victory in the Pacific possible. The commercial stimulation of Merck and Company given to the research of Waksman and his contributing associates at Rutgers University produced streptomycine from *Streptomyces griseus*, a tremendously effective antibiotic which carries on beyond the streptococcus-killing power of the sulfa drugs and penicillin. The dreaded tularemia and undulant fever have been conquered by streptomycine. Can the virtue of such applied science be seriously questioned?

In light of these observations, science educators charged with the leadership, character development, and preparation for intelligent citizenship of young Americans will realize that idealism, realism, and pragmatism are all factors in the community-industry-school interrelationship. In the classroom and the laboratory we shall emphasize the idealism of mutual sharing in creative effort while giving basic training in the fundamental experimentalism of individual investigation. We shall point with pride to the realistic achievements of science, not only with relation to the citizenship involved in earning a living, but with reference to societal ethics.

Limitation of Ethical Responsibility

Science or scientists, however, cannot presume to dictate with positive assurance the path or paths that education should indicate in preparing adolescent boys and girls for lifetime roles in the social order. As has been indicated in the previous chapter, science eclectically reflects some aspects of society while simultaneously exerting profound influence upon it. Alfred Nobel, the Swedish chemist who patented "dynamite" in 1862 and later gave the world powerful explosives such as "ballistite," did so with intense social enthusiasm and altruistic zeal. The resultant misuse of his scientific discoveries caused Nobel a lifetime of misery. The enormous wealth left as his estate, following his death in 1896, has since been administered through awards annually made in world-wide recognition of scientific achievement for the betterment of mankind, in physics, chemistry, and physiological medicine as well as in literature and peace.

The moral as well as the physical impact of atomic energy upon individual, national, and international social welfare is another pertinent example. The original abstract theory of equivalence of mass and energy proposed by Albert Einstein in 1905, wherein the possibility of changing matter into energy and energy into matter was advanced, has influenced and will continue to influence world society to a tremendous extent.[10] Peace or war, annihilation or survival, hinge upon the use or threat of use of atomic weapons.

Chemistry teachers during most of the first half of the century propounded the fact that ninety-two elements were known to science. The blank spaces in the periodic table chart hung on the wall of every American chemistry lecture room were theoretically replaceable by new, unknown elements, yet few chemistry teachers anticipated the recent surge of discovery which resulted in neptunium, plutonium, americum, curium, californium, and berkelium, the elements 93 to 98, inclusive. The uses to which these new elements will be put in the service of mankind are largely unknown today, but an indication of accelerating potential may be gained from the fact that the second atomic bomb dropped on Nagasaki, Japan, on Aug. 9, 1945, was a *plutonium* bomb!

Physics professors (with tongue in cheek) have long taught the theoretical possibility of surpassing the sound barrier in a man-carrying heavier-than-air machine. The sound wall of approximately 11,000 feet per second (varying with the temperature), however, was believed to be extremely dangerous, for both test pilot and fuselage might be buffeted beyond endurance by discontinuances or "shock waves." At subsonic velocities, air particles cushion such an approach *by pushing each other ahead of the plane*, but as velocity passes 11,000 feet per second the air particles are forced *sideways!* Yet supersonic velocity is common today; jet planes in the sky are gone from sight before their passing is heard on the ground below.

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[10] Further discussion and type presentations of energy and matter will be found in Chap. 9, Physics.

What the end results of nuclear fission, discovery of new chemical elements, or supersonic speeds will be is beyond the scope of science to predict. No scientist knows what man will do with his newly found powers for creation of good or evil. Man may destroy world civilization and himself with it, or he may raise the economic, social, and moral level of humanity to undreamed-of heights. Science, in furnishing facts, skills, and method, cannot prescribe the social order. Possibilities may be indicated by science educators, and even probabilities in light of current knowledge and trends, but actualities, never. The scientist cannot evaluate relative social values, for he does not know. Always he must qualify his observations on the basis of present knowledge. Always he must remain humble in spirit, not only in the search for truth and in the revelation of it, but in his attitude toward humanity, which, it is scarcely necessary to point out, includes the young people in his classes.

SCIENCE IN PERSPECTIVE

Another facet of secondary science education which is coming into prominence is the development of historical perspective.[11] This may be brought about through a preliminary survey of prehistoric time, utilizing some of the concepts of historical geology and anthropology, leading to consideration of Greek and Roman philosophic science, thence to a review of maturation from the Dark Ages through the scientific renaissance to the present. It is of importance that such a survey be undertaken, for only against such a background may the true picture of science and the humanities be set forth with clarity and develop-

[11] Strong, E. W., "Why Teach History of Science?" *The Journal of General Education,* Vol. IV, No. 4, July, 1950.

mental sequence.[12] In the field of higher education as related to teacher training as well as in the secondary science classroom, perspective is contributory to education.[13]

The Concept of Time

Geologists and paleontologists tell us that the earth is more than 1,000 million years old, its time span being divisible into five great geologic *eras*. Each of these is divided into several *periods*, which in turn consist of *epochs*. The Cenozoic era, including the four comparatively recent glaciations separated by warm interglacial intervals, culminated in the oligocene, miocene, and pliocene periods, of about fifteen million, twelve million, and seven million years' duration, respectively. The recent period of the Cenozoic era, during which *Homo sapiens* came into being, occupies but the last thirty thousand years. There is no written history older than seven thousand years. Anthropologists are collectively in agreement that if the entire history of our earth were indicated by a twelve-hour day, all human life and endeavor the world has ever seen would occupy only the last *thirty seconds* of time! The extent of this fraction actually devoted by philosophers and scientists to purposeful pursuit of scientific information is measured in its entirety through the last 2,500 years, practically all of our knowledge dating from less than five hundred years ago.

Ancient Science

Hippocrates (460–370 B.C.) is known today as the "Father of Medicine." This early-day scientist and philosophical idealist summed up what was known of healing at the time, practiced the medical arts with legendary skill, and instructed the youth of his country in his techniques. Further, he laid the foundation for the code of ethics which stands to the credit of the medical profession today in the Hippocratic oath, which is taken by every doctor of medicine who graduates from our medical schools.

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[12] Clem, Orlie, "Are You Educated in Science?" *School Science and Mathematics*, Vol. L, No. 9, December, 1950.

[13] Conant, James B., *Science and Common Sense*, Yale University Press, New Haven, 1951.

Aristotle (384–322 B.C.), a pupil of the great Plato and himself, later, the teacher of Alexander the Great, was outstanding as a naturalist. Because of his association with Alexander, specimens were sent to Aristotle from all parts of the then-known world. From serious study of these evolved the first works on comparative anatomy and animal physiology of which there is authoritative record. Aristotle was the first to employ what we today approve as the "scientific method," basing conclusions upon observations and accumulated information. Aristotle, however, propounded the theory [as opposed to that of Democritus (460–370 B.C.) that matter is composed of indivisible "atoms"] that matter and "elements" could be broken down indefinitely. This theory led to later alchemy, in efforts to produce gold from base metals. Although Aristotle's methods were good, his scientific logic was degenerative in effect, and his numerical data were inconclusive.

Galen (A.D. 131–201), a Greek physician to the Roman emperor Marcus Aurelius, did his most productive research in Rome. Galen compiled the lessons of his period into a systematic series of publications on anatomy, and he did much original work in this field. He was a serious and brilliant student but was handicapped by superstitions of his time, which prohibited post-mortem dissections on cadavers by those who were in search of facts. His works, in which he attempted to carry over invertebrate anatomy to the human, are humorous in view of present concepts, but they were accepted as facts during and long after his lifetime. Galen's "book," entitled *Administrationes Anatomicae*, was respected as gospel truth for fourteen centuries following his death.

Middle Age Science

After the fall of Rome in A.D. 410, learning of all forms fell into general disfavor. The works of such pioneers as Aristotle, Democritus, and Galen were possessed by but a few scholars, who interpreted their contents to the masses, the latter preferring to obtain their facts "secondhand." The decline in scientific interest through the Dark Ages was gradual but continuous, gaining momentum as years lengthened into centuries. There were few books, and these were in the hands of indolent, fanciful "teachers," who either accepted as absolute fact all statements found in ancient volumes or embellished the stories found there in order to encourage appreciative attitudes of respect from awed listeners. In the Middle Ages, practically all European learning was possessed by monks. Churchmen, living in great monasteries and controlling thousands of square miles of productive territory, waxed powerful in social status comparable to that of the nobility. There was no such thing as a "general" education as we know it today; a spasmodic movement in this direction established by Charlemagne, A.D. 780, soon died out. It was the custom of the time to keep the rabble submissive, for scriptural writings, in the opinion of those in power, made scientific investigation superfluous. The prime objective of all learning was to save souls.

During this period the diligent industry of many monks was responsible for the careful copying of manuscripts and the transmission of culture, but the end result of most intellectual instruction was superstition and the reaction was that of fear. If, through accident, a young student chanced to make an observation contrary to the teachings of Galen, he believed himself bewitched, and fled to the sanctuary of the nearest monastery to be absolved. There were "purifying" ceremonies, such as burning at the stake and being torn apart by wild horses, available for use upon nonconformists of the day.

Early Arabian scholars also fostered learning in basic science, for Moslem universities at Bagdad and Cordova contributed to applied medicine and natural science. Avicenna (A.D. 980–1037) was a contemporary authority, his Canon of Medicine being widely used by Christians and Mohammedans alike. In general, however, the attitude of Mohammedans toward the Koran echoed that of Christians toward the Bible. The spirit was one of self-sufficiency and religious intolerance. It was not until the dawn of the sixteenth century that there was evidence of independent thought. Doubtless the invention of printing and the subsequent widespread use of books had a great deal to do with this revival of intellectual enthusiasm. The scientific world owes a great debt to Johann Gutenberg (1400–1468), for then, as now, illustrations on printed pages stimulated desire to learn. Interchange of ideas was made practically possible, and scholars began to profit from the knowledge and discoveries of others. It is this interchange which lies at the core of pure and applied science today, for each scientist publishes in his "papers" the results of his findings for all the world to know, to criticize, and to use in pursuit of further knowledge.

When environmental conditions are considered, it is remarkable that any advance whatever was made along scientific lines during that early period. Students of today, working in well-lighted, ventilated, warmed laboratories, with every mechanical aid at their command, have difficulty in imagining the primitive devices used by early investigators and the inhibiting ignorance of the masses. Nicolaus Copernicus (1473–1543) was considered insane on account of his conjectured sun-centered universe, for any fool could see that the earth was flat and stationary, while the sun came up and went down on opposite sides of the heavens. Galileo [whose correct name was Galileo Galilei (1564–1642), although he has been incorrectly known by his given name throughout the centuries since his death] was for a time imprisoned for his insistence that Copernicus was correct, that the earth was a great ball moving around the sun!

The famous gravitational experiment at the leaning tower of Pisa is a classic example of the power of mass psychology and superstition during medieval times. That experiment also marks one of the first times the true experimental method of science ("let's try it and see what happens!") was publicly attempted. Galileo Galilei called together a large group of people and asked them to watch while he dropped two weights from the top of the tower. A small weight and a larger one, obviously heavier, were dropped

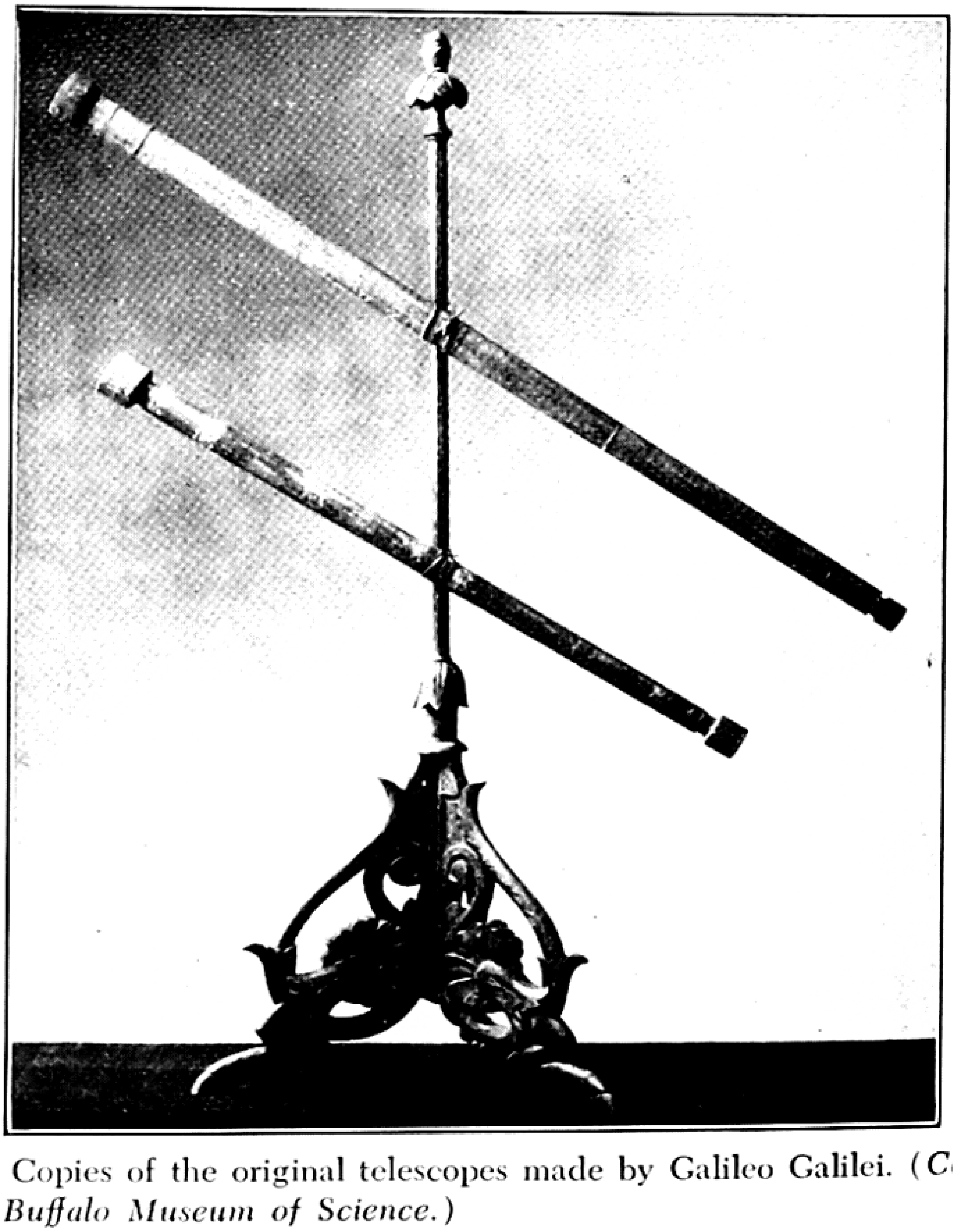

Fig. 4. Copies of the original telescopes made by Galileo Galilei. (*Courtesy of the Buffalo Museum of Science.*)

simultaneously, both striking the ground at the same time. Here were several score witnesses to a demonstration of a basic law of science, but for the most part they refused to believe the evidence of their own eyes, claiming sorcery and witchcraft!

Galilei is noteworthy for his development and practical demonstration of the telescope, among other contributions to science. Without even knowing the name of the "Dutchman" who previously had put lenses from spectacles together in a long tube [generally believed to be Ganseen (Janssen) or possibly Lippershey; the records are hazy on this point] the famous Italian made himself a telescope in the year 1609 and another in 1610 with which he described the mountains of our moon and the satellites of Jupiter![14] As we shall see later, this great scientist also demonstrated the use of the microscope at about the same period. Where Aristotle erred in attempting to make his data fit his ideas, Galileo Galilei was outstanding in carrying the experimental method into practice. In the field of physical science the work of this man marks the beginning of the scientific renaissance.

Vesalius (1514–1563), a Belgian, ranks as the biologist responsible for the restoration of scientific investigation. Believing the ancient treatises of Galen to be in error, he obtained a human cadaver and conveyed it to his home. There, in the dead of night, his dissections by flickering torchlight revealed anatomical truth, demonstrating the fallacies of Galen's descriptions. To proclaim publicly the results of such observations was to invite personal persecution, yet in 1543 the epochal work was published: *De Humani Corporis Fabrica* (The Structure of the Human Body). Opposition from established authority was instantaneous, bitter, and prolonged, but Vesalius's personal vigor and the convincing evidence of his demonstrations won

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[14] Rosen, Edward, "Galileo and the Telescope," *The Scientific Monthly*, Vol. LXXII, No. 3, March, 1951.

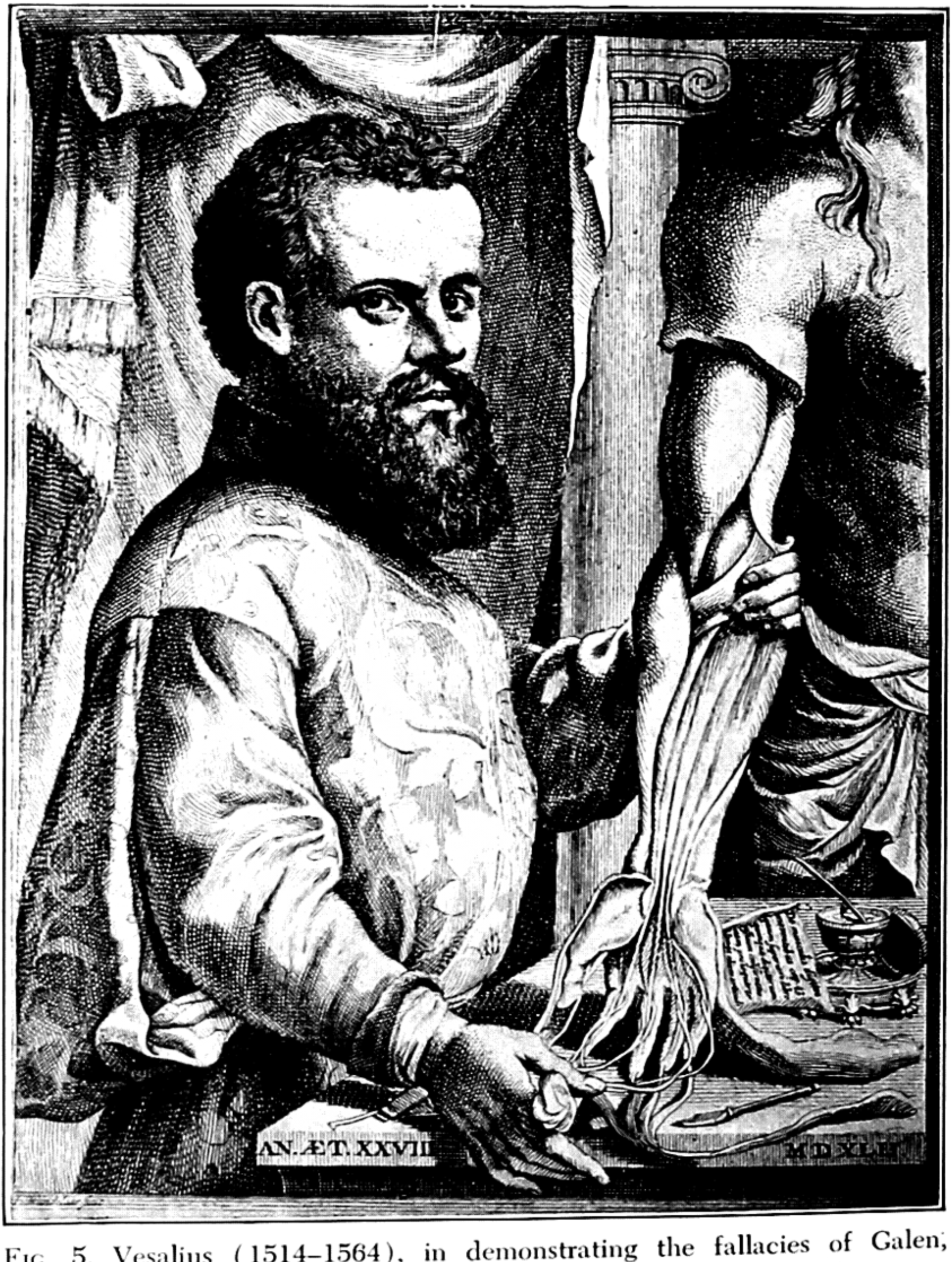

FIG. 5. Vesalius (1514–1564), in demonstrating the fallacies of Galen, brought about the revival of individual investigations in biological science. (*From Locy, W. A.: The Growth of Biology. By permission of Henry Holt and Company, Inc., Publishers.*)

him support everywhere. His efforts, with those of contemporaries such as Galilei, Newton, and Bacon, mark the end of the "dark" ages and the dawn of individual integrity in research.

Modern Science

As Galilei and Vesalius led the way, discovery after discovery was announced, the pendulum of world opinion swinging in favor of learning and investigation. From A.D. 1600 to modern times an unending line of scholars has contributed to the forward progress of science. It is obviously impractical to cover more than a mere fraction of the contributions made by so many workers within the confines of a text on methods, for the field of scientific history is wide and the fertile soil is deep, hence but a few significant achievements will be indicated. Mention of such scientific personalities as Newton, Priestley, Boyle, Lavoisier, Berzelius, Pasteur, Mendel, Darwin, Huxley, Bunsen, Faraday, Charles, Koch, Lister, Gay-Lussac, Dalton, and Curie is sufficient within itself to bring home to the science educator the tremendous possibilities for science motivation and training in method which await employment in the secondary classroom.

The work of Edward Jenner (1749–1823) may be summarized here as an example of application of observation, hypothesis formulation, experiment, and conclusive evidence accumulation in terms of the scientific method. It is quite difficult for us to picture at the present time the havoc wrought by the dreaded "plague," two hundred years ago. Practically everyone living during the late seventeenth and early eighteenth centuries was exposed to smallpox at some time during life. Great epidemics, resulting in thousands of pock-marked faces among the few survivors, were the rule rather than the exception. The well-known "death cart" passed through the streets each morning during epidemics, gathering the dead from each household. Superstition and fear gripped the populace in the face of inexorable peril.

"Plague doctors" appeared in long leather gowns, with leather gloves covering their hands and masks protecting their faces. They wore grotesque false noses in which herbs were continually burned for the supposed immunity thus conveyed. Such "men of medicine" felt the pulses of plague victims with long wooden wands, known as "pulse wands"!

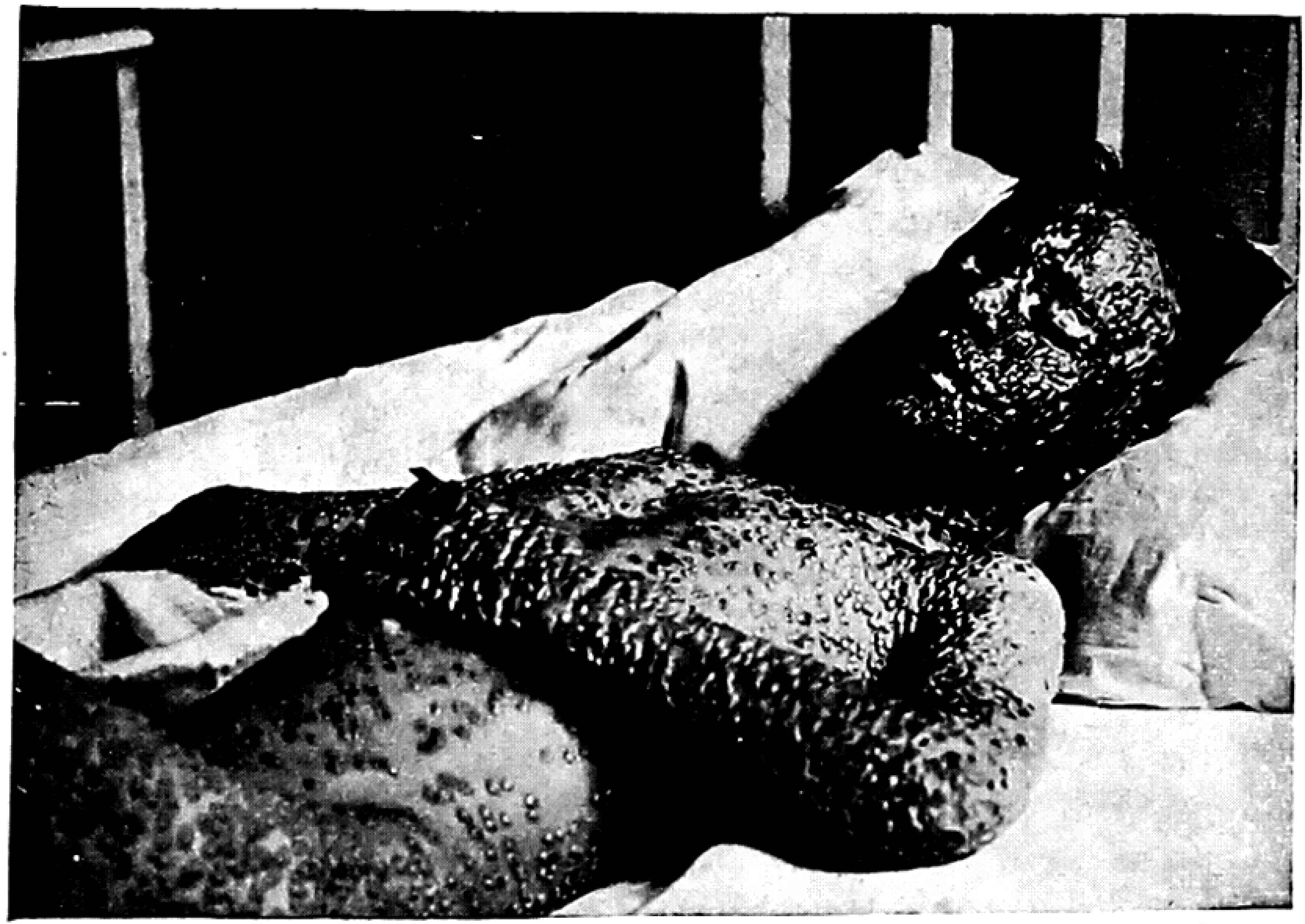

FIG. 6. This is what a severe case of smallpox looks like! Don't you agree that Edward Jenner is deserving of the space accorded him in the text? (*From Burdon, K. L.: A Textbook of Bacteriology. By permission of The Macmillan Company, Publishers.*)

In the midst of all this quackery Jenner appeared, reasoning from his observations that milkmaids did not get smallpox, to the hypothesis that cows might have had something to do with their immunity. His investigations revealed that milkmaids commonly contracted "cowpox," a milker's disease similar to mild smallpox. Reasoning further that the wet, cracked hands of milkmaids allowed infiltration of scum from udders of cows having cowpox, Jenner persuaded the parents of a young man to permit artificial introduction of some of this scum into an abrasion on the young man's body. Thus vaccination was born, the word being derived from the Latin *vacca*, a cow. Through the investigations and tenacity of purpose of Sir Edward Jenner, smallpox has practically been stamped out among civilized peoples today.

The Harvard case-history plan is fascinating with relation to the concepts of science in perspective.[15] Proceeding on the theory that for supreme interest contagion students would derive the most intense satisfaction (effect psychology) from actually having been present at the time and in the laboratory where a great discovery in physical science was made, each pamphlet in the series purports to transport students to the original experimental environment. Here, in spirit, young scholars vicariously experience the thrill of planning, surmounting obstacles, and discovery, through study of one of the classics in physics or chemistry. With reference to scientific method, the Harvard plan, as part of the Harvard concept of general education, tends to increase empiricism through the ideals of pure research, employing a process of "try and find out" according to original hypotheses. Carried to its modern conclusion, the logic of this method transfers pure to applied science in a manner calculated to bring out the best in each, interweaving the paths of discovery and practical application to the problems of society and industry.

No student who works with a microscope can fail to gain interest, inspiration, and perspective through a knowledge of the discovery credited to Ganseen, for example, the spectaclemaker of Middleburg, Holland, who in 1590 put lenses into a tube for the first time, or from the realization that Galilei in 1609 first demonstrated the uses of such magnification. The microbiologist early learns to revere Leeuwenhoek as a patron saint, for his discoveries by means of a homemade microscope, which included both basic forms of unicellular life, protozoa and bacteria. It is amazing to the young physiologist to learn that it was not until Harvey's publication *On the Motion of the Heart and Blood in Animals* in 1628 that anyone understood circulation of the blood. Prior to that time, veins and arteries were believed to be air tubes, and the body a sort of tank filled with swishing blood, which instantly flowed if the tank were cut at any point!

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[15] Harvard Case History Series in Experimental Science (James B. Conant, Ed.), Harvard University Press, Cambridge.

Botanists learn that it was John Ingenhousz (1730–1799) who first observed that green plants when left in sunlight gave off a gas, and utilizing the glowing-splinter test for "dephlogistated air" announced by Joseph Priestley (1733–1804), identified the gas as oxygen. The contributions of Senebier (1742–1809) and De Saussure (1767–1845) to the basic concept of photosynthesis are given meaning in perspective. Zoologists who study the life and work of Cuvier (1769–1832) in comparative anatomy, Darwin (1809–1881) in evolution, and Agassiz (1807–1873) in natural history are the richer for it. Schleiden (1804–1881) and Schwann (1810–1882) show the cooperative spirit advocated today between the sciences in the perspective of their collaboration in advancing the cell theory in 1839.

Chemists respect the quantitative pioneering of Joseph Black (1728–1799) and Robert Bunsen (1811–1899), and revere Antoine Lavoisier (1743–1794) as the father of their science through his careful work with Priestley's gas, which Lavoisier (not Priestley) named "oxygen." Lavoisier coined many chemical terms and cleared up uncertain features of oxidation (rusting) and combustion. The painstaking experimentation of Madame Marie and Pierre Curie, resulting in the separation of radiant barium residue from pitchblende and, finally, in the discovery of radium in 1898, is one of the dramatic classics of science. Physicists thrill to the vision of Isaac Newton (1642–1727) with relation to gravitational attraction and the law "for every action there is an equal and opposite reaction," as well as for his advancement of the "corpuscular" concept, now known as the quantum theory. The theory of equivalence of mass and energy formulated by Albert Einstein in 1905 and the weighing of a single particle of electricity, together with calculation of its electrical charge, by Robert Millikan in 1909 rank among the great achievements of mathematical physics of all time.

As these and hundreds of other advancements in science are noted in perspective,[16] we must remember that science education has but begun. Mankind is as yet only on the outer threshold of the secrets of natural science. What facts and laws will science command a hundred years from now? Perhaps a student in your classes will contribute to the cure of leukemia or other forms of cancer. The common cold, already partially controlled through antihistamines, will doubtless be but an unhappy memory. The coming generation of young scientists will work for the eradication of poliomyelitis and tuberculosis, and the life expectancy will reach a hundred years. We shall fly to the moon and return, as atomic energy, rocket propulsion, and adaptation of new chemicophysical knowledge spurs the field of metallurgy in creation of friction-resistant and featherweight materials. The atomic submarine is a reality, and atomic flight a probability, as we pass into the atomic age of tomorrow.

The Concept of Space

Fantastic as it now appears, the day will surely come when we shall know more of planetary life. Can humans reasonably assume that our planet is the only one populated by living organisms, just because *we* live on it? Physicists have already penetrated the mist and clouds surrounding Venus, using super-radar equipment. The nine *known* planets rotating about the sun are but infinitesimal fractions of the known astronomical bodies. We speak of *the* sun. There are *billions* of suns! All stars are suns, and many of them dwarf ours in size and brilliance. During the early part of the twentieth century the three stars *Betelgeuse, Antares,* and *Mira* (each about three hundred million miles in diameter) were considered to be the largest astronomical unities. Yerkes observatory measured *Epsilon Aurigae* in 1937, announcing the diameter to be two hundred thousand million miles! This means that if the center of that enormous sun were in the position normally occupied by our own sun, its outer edge would encompass the collective orbits of the planets Mercury, Venus, Earth, Mars, Jupiter, and Saturn.

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[16] Cohen, I. Bernard, *Some Early Tools of American Science*, Harvard University Press, Cambridge, 1950.

Light travels at a speed of 186,000 miles per second.[17] Moving with this velocity, light covers almost six trillion (5,865,606,000,000) miles in twelve months. This is the *unit* of measurement in space, known as a "light year." The remote outer galaxies are now estimated to be in motion at a distance of one billion light years (6,000,000,000,000,000,000,000 miles!) from our planet, Earth. In everyday life, we and our students deal with three dimensions: height, width, and depth. The much-discussed "fourth dimension" is *time*. Looking into space by means of the great Palomar telescope, scientists see not what is happening today, but what occurred a billion years ago! Science wonders; science investigates; science searches for truth. Truly we have but begun to learn.

The Scientific Method

Truth

Scientists typically champion truth in any and all forms. It is a characteristic of experienced science educators, as it is the mark of mature men and women in all walks of life, that they are seldom positively dogmatic about any subject. Each has been proved wrong so many times during preparation for his professional career that he has become extremely wary of factual statements unless he is certain of their veracity. Listen to any reputable scientist discuss a field informally; invariably his remarks are qualified by such expressions as "according to the evidence we have at present," "as far as we know today," and other safeguards. To the surprise of many a large audience, a renowned authority occasionally replies to a question with a simple "I do not know; I am not sure."

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[17] New precision techniques developed by Hansen and Ginzton with associates at Stanford University show the actual speed of light to be 186,280.0 miles per second.

Frank truthfulness is the basis of the scientific method. All intelligent effort is directed at securing factual foundations upon which ideas may be based. No scientist will accept conclusions obtained from one, two, or even a dozen case histories; hundreds and sometimes thousands of careful experiments must be carried out, each with proper controls. Hearsay or unsubstantiated "proof" is simply not considered as evidence, for there is little room for "belief" in science. The science man either knows or he does not know. If he knows, he no longer has need for "beliefs" or ideas. If he does not know, his ideas or beliefs have no standing in fact. Theories must be presented as guesses; the apparent logic of a thought does not alter its status in the eyes of science, for it is a theory until shown to be a fact. The cell *doctrine* is a useful example easily comprehended by high school science students, for in little more than a century after its announcement as a *theory* by Schleiden and Schwann in 1839, it has become universally accepted.

Logic

There are two basic schools of reasoning, the deductive and the inductive. Aristotle, in following the deductive process, reasoned from world generalities to particulars affecting individuals and, in doing so, fell into one of the traps of logicians, autistic reasoning of fanciful outcomes. Deductive reasoning is used by science today, but only in cases where there has been a large numerical sampling, a wide coverage to ensure the validity of the original premise. Hypotheses may be set up as a working basis and deductions may be made from these hypotheses in the form of resultant possibilities. Aristotle, the "father" of deductive reasoning, failed to use his own method to best advantage in formulating his own conclusions. This is a "Do as I say, not as I do" philosophy, which the secondary school science educator must studiously avoid, not alone in imparting method in science and logic but in any and all contacts with adolescent youth. Aristotle deduced and inferred on the basis of but a few, or in some cases even single, observations; he failed in constructive criticism of the evidence he did have, and he habitually refused to alter his theories in the light of new facts. Herein lies one of the virtues of perspective in science history, for if your students understand these faults and are enabled to trace their results, they will strive to avoid making the same errors themselves.

Inductive reasoning carries the scientist from particulars to generalities, embodying the formulation of conclusions upon the basis of observed facts and assembled data. In general, science follows the inductive school, although there is Aristotelian logic in scientific orientation of hypotheses also, as has been shown. The crux of deduction must necessarily be subsequent experimentalism and observation, in order that original generalities may be validated. Induction, on the other hand, has its grass roots in experimentalism and observation, proceeding from these to generalities, and science universally approves this in principle. Critical evaluation is essential in following either method, if faith and personal-belief intrusion is to be ruled out. Admission of new evidence is always permissible and desirable, which is a logical postulation in itself.

A word of caution is in order at this point for the secondary school educator: let our criticisms be valid, but gently given; let us avoid sarcasm and ridicule; let us remember always that "the voice with the smile wins." Science, like the youth of our classes, grows and matures continually, progressing through criticism as well as through success.[18] Every science man learns to expect and to take criticism, in turn being critical of the work of others. This is part and parcel of professional training, and it is good, for the expectance of hypercritical reception whets the appetite of the scientist for meticulous accuracy and clarity of meaning while ensuring adequate resilience and defense in depth of statistical evidence. It must be stressed here, however, that such an attitude is that of the scientist at the *end* of his professional training, definitely not the derivative of elementary-secondary sequence and orientation.[19]

Tempering the unyielding attitude of the university science departmental graduate is a perennial objective in secondary method, for the graduate student may have assimilated much science during his long years of serious subject concentration, but this does not imply that through some mysterious alchemy he is *ipso facto* a competent teacher and leader of adolescents. Certainly our over-all objectives of whole personality development and character building are not furthered by spoiling our charges or "babying" them in the laboratory, but the strict, impersonal, almost cruel severity in debate which often characterizes graduate-school science seminars has no place whatever in the secondary school environment.[20]

Procedure

The scientific method is applicable to the solution of many of life's problems, not merely to those associated with the classroom. Essentially it is a careful, analytical way of

[18] Lombard, George F., "Self-awareness and Scientific Method," *Science,* Vol. 112, No. 2907, Sept. 15, 1950.

[19] Smith, Hobart M., "The Search for Error," *Turtox News,* Vol. 29, No. 1, January, 1951.

[20] Lassen, Harry C., "The Scientific Method in Use," *School Science and Mathematics,* Vol. L, No. 7, October, 1950.

ascertaining the real truths in any given situation, and it has attained widespread recognition as a worth-while procedure in educational circles throughout the world. If we accept the concept of secondary education as being concentric in whole-personality maturation cycles and areas of social orientation, we integrate our science and extol the virtues of its operations with relation to life beyond the laboratory. The method can be taught, and practice in its application may readily be obtained in the integrated science classroom as a standard means of problem approach and solution.[21]

A survey of the general field is the first step in a scientific preview of any situation. In this preliminary survey the various divisions and aspects correlated with the whole may be noted and isolated for possible future reference if and as needed. This phase of operation becomes almost second nature in advanced laboratories, wherein specialization has narrowed the field to a point where the investigator may limit himself within it. In the junior-senior high school, the reverse is obviously true, hence continual orientative surveys must be made by students with relation to each problem. The relating of ecological studies in botany to the field of life science, or of chemical problems to physical science, is illustrative of the generalized preliminary survey.

Definition and clarification of the problem constitute the second step in procedure according to the scientific method. Recognition of the problem, which includes a concise but clear statement of it, will be followed by analysis of its various facets in terms of previous experience.

Setting up of working hypotheses follows clarification of the nature of any problem. During this stage, ideas and formulations as to how best to proceed in unraveling the mystery are evolved, checked, and tentatively decided upon. Possibilities are deduced from the original postulation which often influence selection in planning a course of action. The testing of these working hypotheses will follow.

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[21] Nagel, Ernest, "The Methods of Science: What Are They? Can They Be Taught?" *The Scientific Monthly,* Vol. LXX, No. 1, January, 1950.

Evaluation of contributory material is an essential step, which must be taken in the secondary school before any actual testing is begun. The extent of references available and the nature of their information in terms of a high school education must be determined, for assistance of this practical nature, in order to be usable, must be comprehended. Equipment, time, and space available to the student must be evaluated and found suitable, if progress is to be assured and annoying interference with others is to be avoided. This evaluation stage is of most worth when it is mutually done, each student or group suggesting helpful sources to others.

Experimentation is the most extensive phase of the scientific method, for during this period the testing of validity is carried on. Here the student integrates old knowledge and skills in pursuit of new, experiment being a process of continuous scientific growth. As data are accumulated they are checked and plotted against "controls," or observed reactions according to normal conditions. Use of controls must be made clear, utilizing such standard procedures as giving sugar pills to one group and antihistamine pills of identical appearance, size, and sweetness to another in checking the effectiveness of these drugs in common-cold-preventative test experiments. Other factors being equal, the more experiments and the greater number of checks and balances, the better. Variation of conditions with relation to altitude, geographical location, time of day or night, temperature, and other environmental factors usually contributes to greater application to and acceptance of experimental evidence in terms of general conclusions.

Summary of results obtained and a comparison of these results with those of similar experiments in the same or in related fields is next in sequence. The process of organizing and comparing experimental results, together with the work of relating them to each other, to controls, and to other results of other experiments, may and frequently does indicate the gathering of greater numerical or qualitative data and the necessity for further experimentation.

Formulation of conclusion or conclusions based upon all the previous steps is the final phase. Since new science continuously evolves from old, new conclusions postulate new generalizations and stimulate the growth of new concepts. As these are considered with relation to new situations, new problems arise which call for a fresh survey of the general field.

PROBLEMS FOR GROUP DISCUSSION AND REVIEW

1. Discuss the relationship between science learning and democratic citizenship, indicating the role of the high school science teacher with regard to (*a*) mass education and (*b*) leadership training.
2. How would *you* define science?
3. Do you concur in the concept of fusion between physical and life science? To what extent should this integration be carried out in chemistry or physics, for example? In modern biology?
4. Distinguish between pure and applied research, presenting the good points of each.
5. What is meant by "limitation of ethical responsibility"? Elaborate fully upon this postulation.
6. Present in some detail the concept of science in the perspective of time.
7. Present the concept of science in the perspective of space.
8. Why should prospective high school science teachers concern themselves with scientific history at all?
9. To what extent and in what manner should constructive criticism be offered and mutually encouraged in the secondary science classroom?
10. Outline the progressive steps of the scientific method, showing the reason for each procedure with relation to secondary science education.

Chapter 3. GENERAL SCIENCE

The relative position of general science in the curriculum sequence,[1] basic aims and means of attainment, orientation in terms of educational sociology and psychology, and selection of content foundational in the secondary program have been topics stimulative to professional debate for many years. Subject specialists in the higher grades have decried the very existence of such a course, claiming in some instances that it usurps the power and appeal of the secondary disciplines, that it creates a feeling of adequacy where in reality there is none, and that the scope of such a course presupposes intellectual maturity and definiteness of life purpose which does not exist among the pupils enrolled.

Proponents of general science as a preliminary survey course base their case on the opinion that summary and preview studies at this age are psychologically and educationally sound in that they provide for recapitulation, on the one hand, and motivation through stimulative anticipation, on the other. As we survey the situation, support will be given the maintenance and further establishment of general science as a foundational survey stressing content in the physical sciences while offering groundwork in life science, the study attaining a status in the secondary field comparable to the general survey courses commonly presented at the beginning of the college or university sequence in general education. Recommendations will include the use of up-to-date texts, field excursions, correlative extracurricular activities, coordination with other departments (including guidance counselors), demonstrations, and laboratory experiments in providing pragmatic biosocial experiences preparatory to life in and out of school.

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[1] In a few urban systems the comparative-science survey is presented as Senior Science, culminating rather than motivating the secondary curriculum.

Culmination and Preview

Whether the survey is considered as being terminal to an eight-year program in elementary science education[2] or as a motivating foundation for the specialized secondary sciences, the planning of content sequence is a conditioning factor. The word "general" is interpreted in some quarters as being applicable in large measure to physical science, but in many systems and textbooks the term is used in a literal sense to incorporate the elements of life science as well. In some administrative profiles two full school years of the junior high school sequence in science are devoted to this subject, with an approximate year's study devoted to each of the physical-science–life-science fields.

As we coordinate elementary science instruction throughout the first eight years of an 8-4, an 8-1-3, a 6-3-3 or a 6-4-4 program with the specialized departmental plan of the senior high school, we have both the opportunity and the obligation of culminating the collective efforts of many primary-elementary teachers. Life preparation for those young people who are to leave their formal schooling is a very real objective in the terminal situation, for if general science is to function in the social sense, the basis for comprehension of factors affecting the life of individuals in a world society must be summarized here. Our other basic aim is that of providing stimulative preliminary explorations preparatory to broadened studies in the specialized fields of concentration which lie ahead in the senior high school program. In considering methods of presentation in

[2] Wells, Harrington, *Elementary Science Education,* Chap. 9, "Departmentalized Science in Grades Seven and Eight," McGraw-Hill Book Company, Inc., New York, 1951.

terms of these objectives we shall assume that the course is basic in the secondary science sequence, serving both to summarize and to reveal, and that it ranks independently as a subject field, preliminary but in no degree subservient to specialized biology, botany, zoology, chemistry, or physics.

ORIENTATION

Sociological Factors

In dealing with adolescent young people there are fundamental sociological factors which must not be minimized; indeed, success or failure in the general science laboratory may well depend upon the degree to which behavior is recognized in terms of educational sociology. There are two general types of pupils in our American public schools at the eighth- and ninth-grade levels, those who desire and plan to leave school for immediate gainful employment and early marriage, and those whose life ambitions will lead them through the secondary system at least, thence in all probability into higher education.

If administrative authorities are able in practice to distinguish between those who plan to leave and those who plan to stay, the teaching as well as the guidance program will be simplified. The mechanics of such segregation are of course the province of educational administration and will not be treated here beyond an indication of the obvious desirability of full cooperation upon the part of the classroom instructor. Those who are leaving their formal schooling as soon as the compulsory-attendance law allows them to do so will be given broad summary surveys tending to tie in the loose ends of science education, stress being given to applied science and community backgrounds. Fewer experiments, more demonstrations, many field excursions into industrial plants, and a maximum number of group discussions where question-answer sessions will tend to clear up doubtful points—these are the keys to success in a teaching situation where the problem is an immediate one of preparation for citizenship and early parenthood.[3]

The young teacher of general science is particularly vulnerable to criticism in terms of social education, for all teachers teach as they have been taught, to a degree at least, until and unless experience provides indications of desirable change. The college and university professor of science deals with a selected clientele, merged and purged in terms of suitability for higher progression in terms of "grade points," and it is an exceptional man indeed who couples community background and economics with subject matter in the university laboratory. The rise of courses in science methods, the establishment of professorships in science education, and the study of textbooks nationally published in this modern field are self-evident indications of preparation in terms of professional need. Adaptability of instruction to sociological backgrounds is nowhere better illustrated than in the case of handling general science for groups in terminal education programs.

Administrative segregation of those pupils planning to continue beyond the junior high school, on the other hand, will permit the establishment of experimental method, stress upon reading as a learning process, and study as a learning activity which will prepare them for intelligent participation in the subject disciplines which lie beyond. This does not mean that the group guidance of adolescents headed onward and upward will eliminate or minimize utilization of community resources; indeed, in many instances good teaching incorporates even greater emphasis upon school and community coordination, but on a more selective level in the interest of basic subject-matter preparation.

Orientation of students and teacher from the viewpoint of social need in the great majority of schools, however, does not benefit from such a fine line of demarcation between the types of persons with whom the instructor must live and work. Homogeneity is the rule rather than the exception, for the average pupil of thirteen or fourteen does not devote a great deal of attention to such matters as school planning except in cases of economic necessity. During peacetime the trend is to stay in school, youth being carried on gregariously by youth in mass inertia as classmates surge collectively onward until finally weeded out through scholastic competition, love and marriage, or lack of financial support for further schooling. In wartime the reverse is true, mass movement being toward work in munitions plants, factories, or shipyards at good wages for older youths and girls, followed by early entry into the armed services, merchant marine, or other communal endeavor.

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[3] Simmons, Maitland P., "Yours for the Doing. A Unit in General Science," *School Science and Mathematics,* Vol. LI, No. 1, January, 1951.

Psychological Factors

Naturally these forces integrate with one another, being noticeable when dissected and laid bare through analytical study; each is in some degree psychological as well as sociological. Extracurricular activities, for example, provide material for careful consideration in terms of underlying causes as well as social effects, and both sets of factors have intense bearing upon success in the classroom. Things done out of school become of relative importance in the scheme of life for adolescents, for in the last years of the junior high school, as well as during the first year of the standard four-year high school, the instinct to club together for mutual welfare is exceptionally strong.

Wise administrators and science educators make ample provision for this gregarious trend within the framework of the school through the establishment of various types of science clubs, nature clubs, hiking clubs, hobby clubs, and home-room activities,[4] while collaborating to the fullest extent with such community organizations as the Junior "Hi-Y," the Junior Red Cross, and the Boy or Girl Scout troops. Classroom activities of a type which coordinates naturally with youthful extracurricular interests, such as learning the names and descriptions of fishes inhabiting streams flowing nearby, in order to exhibit leadership on the next "fishing club" expedition, exemplify means of stimulative integration which operate favorably at this age.[5]

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[4] Fedder, Ruth, *Guiding Homeroom and Club Activities*, McGraw-Hill Book Company, Inc., New York, 1949.

FIG. 7. Integrated science training carries over into extracurricular activities. An eagle scout checks on the Morse-code proficiency of three fellow students, as part of the Boy Scout program. (*Photograph courtesy of the Westinghouse Electric & Manufacturing Company.*)

Guidance is of paramount significance during the time young people are enrolled in general science, and each teacher can do much in each individual case if he will give serious attention to cooperation with the school and/or central office counselors. There are powerful psychoses operating or in the formative stage, in addition to the normal problems collectively accompanying the business of growing up physically, mentally, and morally. World problems of international stress and strain, warfare, fear of bombing or invasion, wild tales of beings from Mars flying about in aerial saucers—these and a score of other abnormal psychological factors affect the attitude of young people toward their homes, their schoolmates, their teachers, and their future lives. The science teacher has a very real job to do in connection with such abnormal evidences of pseudo science as are heard every day over the radio; read in the newspapers, comic books, and cheap magazines which are always present with youth; and seen in the deplorable movie thrillers omnipresent on the "double-feature" billing at side-street motion-picture theaters.

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[5] Palmer, E. Laurence, "Fish and Fishing," *Cornell Rural School Leaflet,* Ithaca, N.Y., Vol. 44, No. 2, November, 1950.

Basic factors operate also. This is the "gang" age—the "clique" age—in which boys and girls tend to run in packs, assembling in small or large groups for psychological support.[6] Friends become very dear friends; other humans simply do not count. Home and family are matters of secret or open pride, on the one hand, or matters of quarrelsome distaste, loathing, and very real shame. To own or not to own an expensive car, to have or not to have one's own room, to possess a television set in the living room or a "hot rod" in the driveway are matters of social caste. The very town or city in which the school is located is a matter of provincial pride extending to such criteria (from the youthful viewpoint) as the number of outdoor theaters, the size and relative glamour of dance halls, and the comparative seating capacity of the municipal stadium.

The school itself metamorphoses from the taken-for-granted elementary plant to a position of social and psycho-

[6] Jones, Mary C., and Bayley, Nancy, "Physical Maturing among Boys as Related to Behavior," *The Journal of Educational Psychology*, Vol. 41, No. 3, March, 1950.

logical dominance. In some sections of some of our American cities, one's mere appearance upon the playground of a school not attended is indeed an open invitation to physical combat! School loyalty as demonstrated by massed groups of "rooters" at athletic contests is an interesting and indicative phenomenon. In the world of young people, the all-important urge is to belong, to do the accepted thing, to wear the right clothes, to appear at the proper places, to speak current slang. These observations are not new in a historical sense, but they are new in terms of each individual, and they are of far-reaching significance in terms of educational psychology.

The onset of puberty is a dominant psychological factor at this age, especially among the girls.[7] This is the period of breathless experiment with pancake make-up, lipstick, high heels, and nylon stockings. This is the strutting time marked in all animal males as sexual maturity approaches, a time when cigarettes, pool, fast cars or horses, and an overpowering need for money occupy the minds of young men.[8] Consideration of such sociological and psychological factors is predominant in this book, for these things make the difference between success and failure in so far as they affect classroom attitude, and they are all-important in terms of their bearing upon the completely rounded development of each student as an individual. Just as the curriculum of the secondary school is following the lead of higher education in turning from emphasis upon subject detail during formative periods to stress on principles in general education, so the teacher of general science organizes his thinking and instruction in terms of adolescent problems and needs.

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[7] Fedder, Ruth, *A Girl Grows Up,* McGraw-Hill Book Company, Inc., New York, 1948.

[8] McKown, Harry C., *A Boy Grows Up,* McGraw-Hill Book Company, Inc., New York, 1949.

SEX EDUCATION

Probably the most controversial and difficult orientation problem facing the inexperienced teacher of science at this grade level is the matter of degree of enlightenment regarding sex and the enmeshed tangle of human relations which is interrelated with it. Against the backdrop of Freudian psychology involved, let us briefly examine this specific problem situation in order to distinguish, if possible, the role a really competent teacher may play in terms of human understanding, science content application, and wholesome character development.

In the first place, we know that in many instances sex facts are presented too late. The "sex assemblies" held in the senior high school during the 12A semester (still common practice in some centers) are worse than useless; they are horribly embarrassing to some and laughable to others. Not infrequently the majority of young people seated in the auditorium have had considerably more experience in such matters than the speaker! This is not meant to be humorous; it is merely true. In the second place, the fact must be recognized that there is *opposition* to any teacher group taking upon itself the prerogative of sex education in the public schools, objections arising from many parents, from some churchmen, and even from members of the teaching profession itself.

From Whom

Education along such lines as intimate sex education is admittedly preferable when taken up informally within the bosom of the family, amid a sanctity of trust and confidence which outside sources may but simulate. Heart-to-heart talks between father and son or between mother and daughter are the ideal before which all educators bow very low in principle. The only trouble is that such occasions never seem to arise in the overwhelming majority of homes, for well-meaning parents tend to rationalize and to postpone, with inevitable results. A sense of delicate, mutual modesty develops; defense mechanisms spring up; a gruff "trust him to find out about that sort of thing" attitude erects intangible barriers between members of the family circle which become almost insurmountable. All parents who consider the matter at all *intend* to take the matter up someday. A few drive themselves to it, isolated retirement behind the folds of the evening newspaper providing welcomed refuge following evasive answers to a few clumsily put queries and parrying statements designed to ward off further interrogation. In few nonprofessional families, indeed, is there genuine understanding and thoughtful sex guidance.

The general veracity of this picture will readily be admitted by honest adults who have worried through this period of child maturation. No parent may reasonably be considered at fault, for how many mothers have had training in psychology, physiology, sociology, and hygiene? How many fathers can distinguish fact from fallacy in matters commonly bandied about in poolrooms, bars, beer parlors, clubs, and on street corners? Even when information obtained from sincere effort at careful investigation is substantially correct, how many average parents have experienced reliable schooling in scientific exposition or in those backgrounds of plant and animal biology which render such materials smooth and natural in unembarrassed assimilation?

The religious counselor is turned to in such cases by a small minority of young people, sometimes in company of one or the other parent. Here again we have difficulty in securing genuine guidance from minister, priest, or rabbi in terms of life contacts, assuming that the real problem cases actually contact the adviser, which is doubtful outside the parochial school. Physical contact, lust, temptation, and the run-with-the-pack urge are not always familiar to the cloistered halls of the church or to the persons who dwell in them, and sex intimacy is scarcely a problem of moral right or wrong when the hot blood of passion first pulses in red lips and trembling young bodies.

There remains one avenue of counsel other than the public school—the family physician, if there is one. Not all families today enjoy the confidence of a man of medicine. Particularly in our cities, the age of specialization has developed specialists here, as elsewhere; "clinics" have supplanted the doctor's "office." To pass the line-up of desks and inquiring appointment clerks has become an accomplishment for an adult with an A-1 credit rating. What must it be for a child in semineurotic fear? In theory the doctor can do a good job, provided emphasis is placed upon moral and mental health rather than upon pathologically dire results of sexual promiscuity, and provided he knows the young person intimately. Fear of disease never stopped a young lover yet, for disease is not apparent; it comes later if it comes at all, and the moral damage has been done; the flower is wilted; the fruit is decayed.

No teacher of any subject should attempt to handle sex alone and unaided, for this problem, like that of evolution in a former era and that of religion in the classroom today, is fraught with pitfalls and professional dangers. Sex education is the common business of those who through professional training in methods of integration and presentation, long years of study in the fields of psychology, educational sociology, and mental hygiene, together with biology, physical and health education, have become ingrained with reverence and insight, as well as scientific background. Especially it is the province of those engaged in the teaching of science and physical or health education.

Where

In our daily living outside the school environs it is the beach or the lake which provides the background for building appreciation of health, vigor, and clean, sound bodies, as opposed to stress upon sex. In these situations American young people habitually appear in abbreviated garments, yet no one thinks much about it, for such apparel has become the custom; it is commonly accepted. At our American beaches appeal and glamour through the possession of a fine young body, tanned and healthful, is the ideal sought after by all; there is little or no intrusion of sex in beach enjoyment, while young people play games on the sand or dash into the breakers.

Within the departmentalized secondary school an analogous situation exists on the playground and in the gymnasium, for here we find enjoyment, healthful play and relaxation, abbreviated clothing, and unaccented, natural, matter-of-fact sex segregation. The latter point is quite important, for the unnatural, rigidly supervised, suppressed "sex assemblies" of former years have no place in this program. If the science instructor will confer with the physical education supervisors of both sexes, a program of sex enlightenment will be worked out which will have none of the psychological drawbacks of other methods. Some of the instruction may best be given by health education people; other subject matter may be correlated in terms of scientific education, but the time and place of such analysis should be the "gym" period, in the school gymnasium, under administrative supervision of the counseling and guidance office.

When

With biological backgrounds built up through the use of audio-visual aids[9] and life-science lectures on comparative reproduction, factual information on sex organs and hygiene, together with moral conduct of young ladies and gentlemen, may be presented at the grade level best suited—earlier for the girls than for the boys because of generally varying puberty, but early enough in either case to be effective in prevention of the disasters which have become all too frequent in our American society since the advent of the motion picture, the wars, the psychoses of divorced and broken homes, and similar factors which have tended to break down the morals of the young. There is scarcely a person in the teaching field today who could not, if he wished to do so, provide one or more personalized instances of such character devastation, often from among our "best" families. "Better a year too soon than a minute too late" is a pertinent maxim.

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[9] Text films may be employed, as with Hurlock, Elizabeth, *Child Development,* McGraw-Hill Book Company, Inc., New York, 1950; and Beck, Lester, *Human Growth,* Harcourt, Brace and Company, Inc., New York, 1949.

Timing at the end of grade 8 or the beginning of grade 9 for the girls, and the end of grade 9 for the boys, is in the opinion of the author the optimum in terms of effectiveness. This places obligation squarely upon the shoulders of the instructor in general science or in general biology, and it allows time during the secondary school sequence for personalized counseling and guidance if individual attention seems indicated in isolated cases. Such a spirit of cooperation between departments of science and physical education, on the one hand, and the guidance offices, on the other, will produce educationally approved action and over-all community approval. Science classroom libraries will include copies of the best references on maturity and child development, and general science or biology topics correlating with conservation of personal health and comparative reproduction will be timed so as to coincide with the segregated group presentations in the gymnasium, if sex segregation has been administratively extended to include actual class enrollments, as is frequently done in educational centers where there are adequate instructors of both sexes available.

What

As has been indicated, sex education is a dangerous phase of secondary science. One of the problems which must be met, whether we like it or not, is that of *how much information of what kind*. What the young married couple should know, and what the engaged couple should know, are quite different phases of informative sex-relation subject matter from that which should be placed before thirteen- and fourteen-year-old children. Sex education in the public schools should studiously avoid any and all obscenity, together with reference to erogenous areas of the body, positions during human intercourse, or other sexual techniques. Homosexuality should not be overly stressed, nor should any of the subject matter of abnormal psychology be brought into the picture. Birth control should be discussed in the abstract only; absolutely no information of any kind should be given out from the lecture platform or privately by any teacher. There are varied beliefs concerning the use of contraceptives, on moral as well as religious grounds, and these should be respected.

What, then, should be included, and on what basis? In general, basic backgrounds of biology are essential. There is no adequate substitute for the "birds, bees, and flowers" approach. To deliberately employ such terms, smilingly but in semiserious vein, is the technique used by the author. Progressing smoothly through health education fields, the young audience is led to consideration of social and ethical views. Mutual faith, trust, love (as opposed to lust), character, and honor are held sacred in preparation for marriage, homemaking, and parenthood.

Environmental Backgrounds

Where sex segregation is impractical in the laboratories during the period sex education is carried on in collaboration with physical education and guidance personnel, display cabinets in classroom and corridors which are at the disposal of the science department may feature indirect lessons of the natural history type throughout the year. Wild-flower, animal-specimen, and plant-animal interrelationships may be indicated, and students will learn directly or subconsciously without the furtive sneaking and whispering embarrassment which has characterized overblunt campaigns in the past.

Display cases [10] form a definite part of the visual mechanics of instruction here as elsewhere, being coordinated with sex education through dioramas depicting the balance of nature. Mutual dependence in such cases as the Smyrna fig and *Blastophaga grossarum* or the yucca of the desert Southwest and *Pronuba yuccasella* are examples of art-science correlative endeavors which may be utilized to advantage. Symbiosis generally has a strong appeal to students of high school age, being related in cooperative endeavor and "teamwork" in the world of nature to the psychological leanings of maturing youth previously discussed in this chapter. Environmental influences play an important part in creating the naturalism desirable in the correlation of science teaching to character and citizenship training.

APPROACH

In attempting to make provision for motivating preview stimuli, together with adequate coverage throughout the areas of "general" science with which the average person will come in contact during adult life, teachers (and authors of ninth-grade textbooks) have tended to lead young people toward the twin pitfalls of confused frustration and pseudo knowledge which today are being recognized and to some extent avoided. In connection with these dangers, the demonstrations which are currently popular because of ease of handling topics and large classes, and which are perennially favored by administrators because of simplified sectioning, are often as much at fault as the time-honored experimental method to which many experienced educators cling in terms of personalized experiences.

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[10] Ames, Clarence E., "The Use of a Display Case for Science Education," *School Science and Mathematics*, Vol. 50, No. 7, October, 1950.

Demonstration Method

There can be little question as to the lateral spread of general science as a subject; the problem is one of emphasis and approach, plus careful attention to developmental sequence in content. Permitting facile coverage, the group lesson in or out of the laboratory is versatile in many ways, including motivation, explanation, thought stimulation, exemplification of techniques, and refresher-type lecture reviews. In addition, the demonstration method is of peculiar value to students in the ninth grade when employed in culmination or summary of subject matter previously covered in the upper elementary grades.

It is becoming more evident each year, as the backlog of increased attention to elementary science is built up, that young boys and girls of junior-senior high school age have a "speaking acquaintance" with a great many topics heretofore unfamiliar prior to the general science course. Often the class group pre-test will reveal a partial knowledge of content which may well be integrated and expanded through use of the demonstration approach. Many times, the actual demonstration may be used as an evaluation instrument, measuring the quality and quantity of previous instruction, if leading questions are put to individual members of the class at various stages and in key situations.

There are many criteria related to demonstration teaching skills. In the first place, every demonstration should be followed by class discussion. There is no substitute for socialized interchange if the real values lying behind the demonstration are to be made clear to all. Each person in the receptive group must be led to desire the demonstration if it is to be effective; if one or two young people seem to be above the need for further work along the line indicated, they may be called upon to perform the demonstration themselves or to assist in performing it. Everyone must be able to see clearly, as well as to hear distinctly what is being said. The instructor should check every step of the operation in advance, in order to be certain that everything will work. Students should all know the name and nominal uses of each piece of apparatus; there should be no attitude of side-show mumbo jumbo. Finally, the demonstration should prove functional in terms of principles and applications.[11]

Experimental Method

It must be borne in mind, however, that much of the content which the modern departmentalized teacher has in store for his youthful investigators is *new* in the sense that no real depth areas have as yet been explored. Student interest whetted through facets shown in demonstration must neither be allowed to wane through lack of "follow-through" nor to cause invasion of intellectual depths not commensurate with the maturation and life experiences of the class. Use of correlated laboratory activities [12] will allow time for reemphasis of points made during demonstrations and will simultaneously provide for recapitulation through pragmatic personalized experiences in basic problem solving. A combination, then, of teacher demonstrations plus individualized laboratory and field observation and experimentation, including methods of result recording and conclusion drawing must provide our scientific approach. Both methods have merit, and both will be employed by competent personnel.

Socialized Discussions

Just as the *seminar* is the instructional device most appreciated in the upper division and at the graduate level in the college and the university, and the *panel discussion* the modus operandi of the teachers' institute, so must the socialized discussion be found essential to real mastery throughout the secondary science field. If firm values are to be entrenched, the scientific method inculcated, and problem cases eliminated in the light of mutual help and understanding, oral intercourse must be interspersed between the demonstrations of the teacher and the experiments of the students, as well as in summary. Workbook conclusion recording "in the spaces provided" or teacher-student "question-answer" periods are not enough; socialized interchange is the realistic as well as the ideal method, giving optimum results when all persons (including principal, supervisor, and visiting parents, if any) witnessing demonstrations or experiments join in the interplay of discussion in terms of adolescent preparation for life.

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[11] Richardson, John S., and Cahoon, G. P., *Methods and Materials for Teaching General and Physical Science*, Chap. 2, "Using Demonstrations and Laboratory Experiences in Science Teaching," McGraw-Hill Book Company, Inc., New York, 1951.

[12] Davis, Ira C., "A Plan for Laboratory Activities in General Science," *School Science and Mathematics*, Vol. XLVII, No. 2, February, 1947.

CONTENT

A prime criticism leveled at general science as organized classwork, as well as in textbook form, during the quarter century this field of specialization has been operative in secondary schools, has been the "shotgun" intermittent sequence and heterogeneity of content characterizing the work. Texts (and teaching lessons based upon them) blithely leap from "Radio Broadcasting" to "Bones," and from "Soil Conservation" to "The Automobile," thence to "The Story of the Earth," for example, in otherwise excellent presentations. In order to be effective in foundational terms, sequence must be coherent and understandable, even to the dullest student, and will build logical progression in itself.

Life Science

Studied progressively since the primary grades, environmental observations of living things attain recognition as a foundational preview of later specialized study in biology, botany, and zoology in the optional senior high school curriculum. The modern course in general science also includes correlative studies in the life-science fields for the benefit of the large numbers of young people who will leave their formal schooling at the end of the period of compulsory attendance. Interrelationships, economics, principles of personal and community health, and social integration of such phases of citizenship education as conservation of natural resources are features. Courses to follow in the senior high school curriculum will take care of breadth and degree of specialization; the basic problem remains one of solidity in foundational groundwork and scientific attitude establishment in terms of functional application.

Laboratory experiments with plants,[13] which have been found especially effective in bringing about desired training at this age, are highly recommended in connection with the life-science phases of general science. Whether undertaken at the eighth or the ninth grade, these individualized and collective lessons in experimental biology have excellent repercussions as regards attitudes toward the living world and with regard to scientific research generally, and they have none of the undesirable qualities associated with animal experimentation. Lessons learned from the plant world are, indeed, most readily transferable to animals, including man; and methods of inductive science are ideally demonstrated.

Physical Science

The pupil immaturity which until this time has made the grasp of physical concepts somewhat difficult being past now in most cases, attention may be focused upon principles related to planetary astronomy, weather and climate, physical geography, and geology. The elements of chemistry and physics now assume dominance in the year's course of study, including the basic element cycles in nature as a transition topic from life to physical science, the roles of fire in creating heat and steam, as well as in internal combustion engines (a facet of tremendous motivated interest among the boys who have "hot rods" or envy those who do), electricity and its uses, radio, light as a factor in photography, and the application of light in motion pictures and television. Other physical science topics touched upon include sound, sound "tracks," and sonic speed, as well as uses of radar in peace and war.

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[13] For detailed outlines of experiments, see Wells, *op. cit.*, Chap. 11, "Laboratory Experiments with Plants."

Culminating content may well feature airplanes, air maps, and air transport, including the latest released developments in jet propulsion.[14] Every boy has his eye on the Air Force as a highly selective modern branch of military service, and control of the air being a dominant social science topic, school-life correlation and motivation are established. Atomic energy and atomic bombs logically follow in sequential interest. Hence, a ground-level basis for civilian comprehension may be presented solidly if it is prepared on the beginner's viewpoint of atomic structure and carefully built up to an inclusion of protons, neutrons, and electrons in the young scientists' vocabulary. Later analysis of energy in the senior high school will review this basic coverage,[15] and the students leaving their schooling at this time will have been exposed to the terms, in any event.

In connection with technical phases of science instruction such as that related to any real understanding of atomic energy, the fact must constantly be borne in mind that these pupils are still very young. Hence, too much drill in mastery of chemicophysical and arithmetic detail will prove utterly disastrous. Most of the trouble experienced by general science teachers is directly traceable to attempts at inclusion of portions of the teacher's own college courses in astronomy, meteorology, mineralogy, inorganic chemistry, or general physics, without drastic simplification in terms of fundamentals. Content assimilated with no little difficulty during the period of college lower divisional basic teacher

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[14] Albertson, E. J., "A Jet Model That Works," *The Science Teacher*, Vol. XVII, No. 5, December, 1950.

[15] Chap. 9, Physics. In some institutions, "Senior Science."

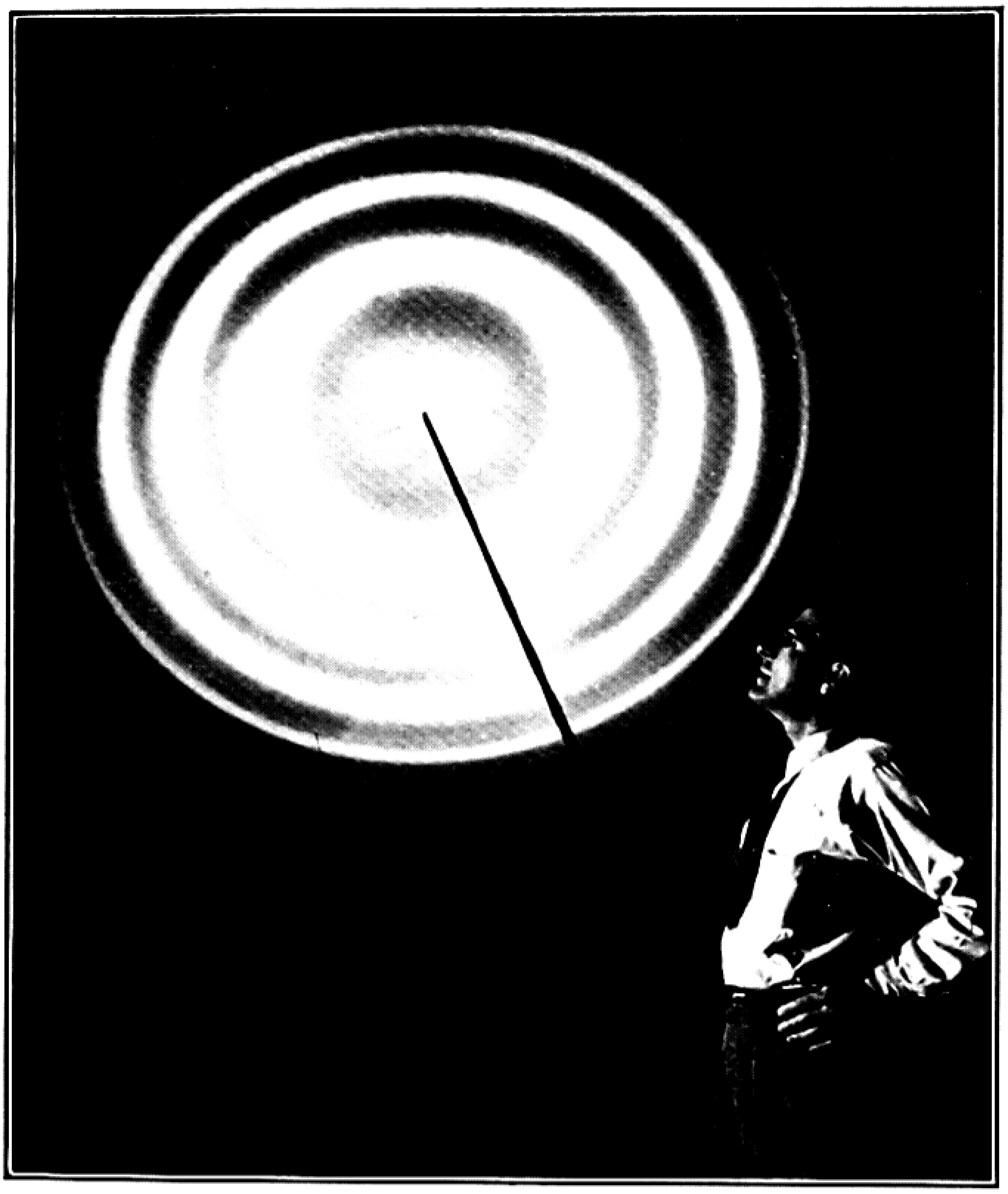

FIG. 8. The spirit of scientific endeavor, as well as world implications of scientific research, is shown in the development of a new international unit of measurement which will never change and never be lost. Bombardment of mercury vapor with ultrashort waves causes it to glow, the light being broken up into various wavelengths and recorded in concentric circles on a photographic plate. At present the international standard for the meter is the number of wavelengths of red light emitted from the element cadmium, which has an accuracy of one part in ten million. The new standard, *if confirmed in three separate laboratories in three separate parts of the world,* will raise the standard of accuracy to one part in *forty* million! France and England are currently at work on the same problem. (*Photograph courtesy of the Westinghouse Electric & Manufacturing Company.*)

training has no direct transfer value *per se* in ninth-grade general science.

The ideal toward which every leader of student thought should strive at this stage is portrayal of the *spirit* of scientific endeavor, with revelation and attitude creation as primary objectives. The study of mineralogy, for example, will provide the keys to comprehension of fundamentals, but will do so through revelation of the marvels of fluorescence and phosphorescence under ultraviolet light. Wonderment leads to inquiry in terms of "why" and "how," and application of observed and recorded phenomena to the field search for strategic minerals follows as day follows night! Those science educators who immediately succeed the instructor of general science in the secondary school and college will build in skills, mastery, and breadth if the spirit of eagerness in learning and scientific curiosity has been inculcated.

The socialized approach in fundamental attitude creation and stimulation of critical analytical thinking through interchange of ideas will bear fruit in citizenship for those who leave school to enter business, whereas extended disciplinary drill in a compendium of subject detail would but add to the multitude of adults who cannot see the forest because of the trees. If fundamentals are substantiated through demonstration and experiment, and if basic concepts are recapitulated through socialized discussion, the science educator in charge of general science will have done his work well.

Basic Element Cycles

As an illustration of *exemplary content*, the oxygen, carbon, and nitrogen cycles are of fundamental significance. Ninth-grade students all realize that oxygen in air and water is a cellular necessity for animal life, but not everyone will understand that plants get air for the same functional reason. Detailed study of the chemical processes involving carbon compounds may be delayed until students are enrolled in botany, biology, or chemistry, but basic implications of this underlying interdependence of biophysical entities may be emphasized here as a fundamental cellular process. The general role of carbon as it is involved in photosynthetic activity together with release of free oxygen as an end product will promote socialized discussions of city parks in slum districts and in residential areas, or why it is considered healthier to live in the country than in the city.

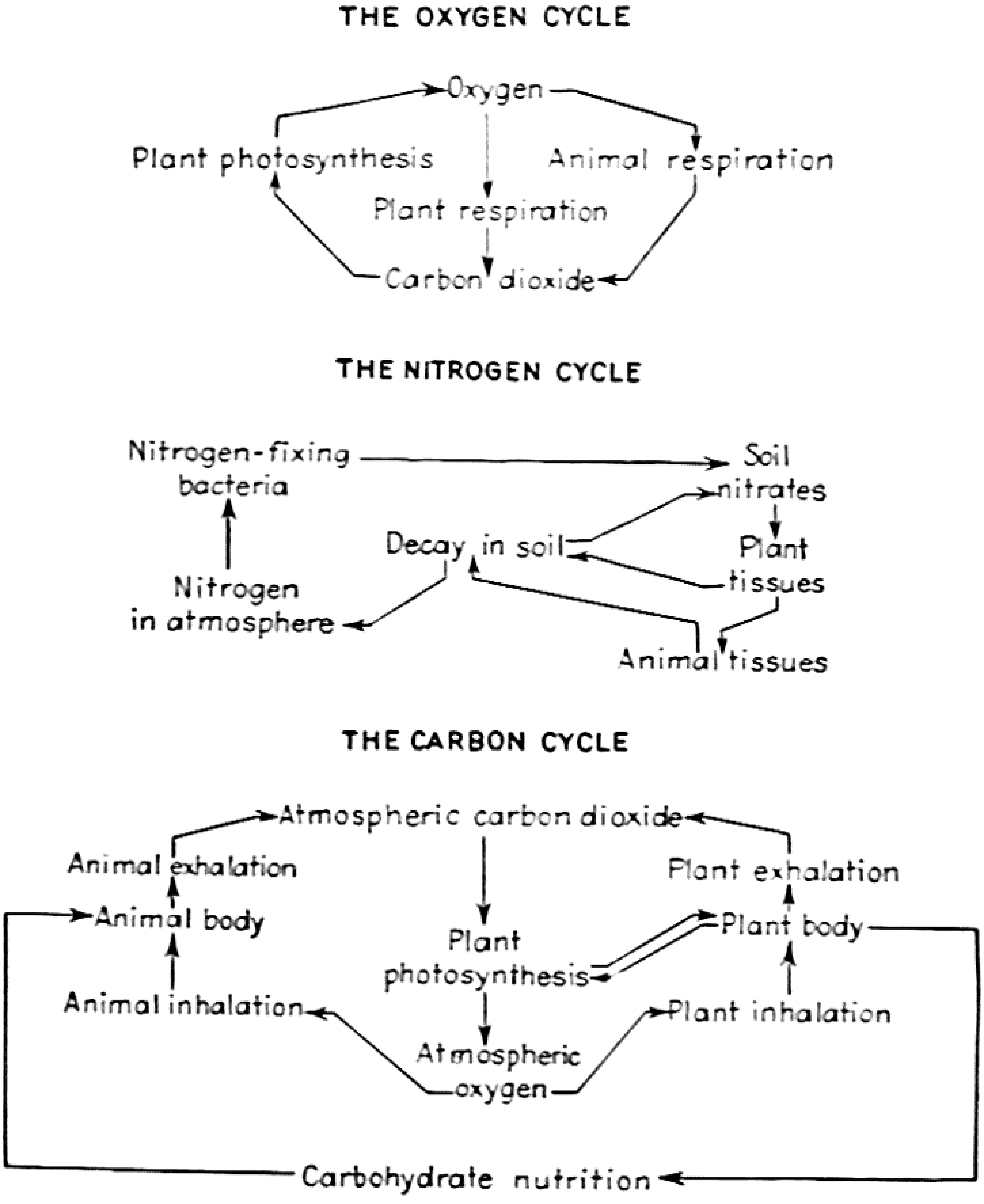

FIG. 9. Diagrammatic representations of the chemical element cycles in nature, important foundational concepts in general science. (*Prepared in simplified form by the author.*)

The teacher in a suburban community school may ask the question, "How many members of the class have fathers who 'commute' to the city for work every day?" The resulting discussion may lay foundations for later work in social biology[16] which will include studies of our city, state, and national forests and parks. An interesting metropolitan class project might be to ascertain approximately how much the land is worth which Central Park occupies in New York City!

The nitrogen cycle is also basic in general science content. Air is approximately four-fifths nitrogen, a fact which most adults do not know. The element is a principal constituent of protein compounds, and as such is needed by all animal bodies, including those of the students in the room. Even with this superabundance of free nitrogen available in atmosphere, however, animal bodies which need it so much are unable to utilize it directly. Student research teams will reveal to the group that it was during the First World War, when Germany was cut off from the world's source of sodium nitrate in Chile, that German scientists developed the Haber process of "fixing" atmospheric nitrogen, American production of synthetic commercial fertilizer and war-use nitrates following. Correlations with geography, chemistry, and economics are self-evident, leading to broadened outlook and appreciation of the values of scientific research.

Elaborating upon this phase of the unit being studied, students will have occasion to examine closely the assimilation of nitrogen for plant and animal body needs. Animals get nitrogen from plants in nature, which in turn obtain it from the soil in which they grow. "Nitrogen-fixing bacteria" living in nodules on the roots of peas, beans, alfalfa, clover, peanuts, and other leguminous plants convert atmospheric nitrogen into soil nitrates. Soil bacteria of similar type such as *Clostridium pasteurianum* and *Anzobacter agile* convert nitrogen to nitrates in like manner. Since leguminous plants of the types mentioned put nitrates into the soil, they are widely employed in "crop rotation," which provides another broad discussion topic correlating chemistry, biology, and botany in terms of natural-resource conservation.

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[16] Chap. 5, Social Biology.

In the type lesson presented above, correlative steps emphasizing interdependence of the sciences are indicated. Studies of atmospheric air may lead to discussions regarding the universe, and astronomy to seasons, tides, weather, and man's control of his environment. Light from a star is seen through a telescope and photographed by a scientist. How does the scientist "see"? What relation has the human eye to a camera? As each query takes the form of a unit problem, associated sciences contribute information and new problems arise.

COURSE OUTLINE FOR GENERAL SCIENCE

- Unit I. "Introduction to Science."
  - What *is* "General Science"?
    - Relationship to elementary science.
  - Why should we study General Science at this time?
    - Survey of world events.
    - Importance of scientific knowledge to all of us.
      - Future use in school and college.
      - Future use in the home, in the community.
      - Present need for knowledge of "how" and "why."
  - How shall we study General Science?
    - Use of the "scientific method" in learning about things.
      - Surveying our field of study.
      - Deciding upon our objectives.
      - Locating and evaluating helpful materials to work with.
      - Experimenting for ourselves.
      - Observing for ourselves.
      - Watching demonstrations by the teacher and by each other.
      - Library and community reference and source work.
      - Individual and committee reports.
      - Discussing each other's findings.
      - Summarizing our results.
      - Drawing our conclusions upon the basis of our results.

- What science shall we study?
  - The history of our earth.
  - What the earth looks like today.
  - What the earth is made of.
  - Weather and climate on our earth.
  - Plant and animal life on our earth.
  - Physical factors which affect the lives of living things.
    - How astronomy affects the earth and life upon it.
    - What forces on earth affect the lives of living things.
      - How these forces in our environment may be controlled.

Unit II. "What Should We Know about Our Earth?"

- Geology and Paleontology.
  - The "record of the rocks."
  - Outline survey of historical geology.
    - "If the age of our earth were represented as a 12-hour day, man's time on this earth would be 30 seconds!"
  - Outline survey of physical geology.
    - Erosion.
      - Glaciers and their work. Evidences of action.
      - Wind and water erosion. Evidences of action.
    - Volcanoes and what they mean.
    - Earthquakes and what causes them.
      - How scientists are able to predict earthquakes.
      - How earthquakes are recorded on instruments.
    - Land forms.
      - Local environmental studies of land forms.
- Outline survey of Mineralogy.
  - What are minerals?
    - Chemical "elements" in combination.
      - Review of "element" concepts of elementary science.
  - What kinds of minerals are there?
    - Crystallized, massive, compact, artificial.
      - Examples of each type. Field collecting.
  - What are rocks?
    - Minerals in combination.
  - What kinds of rocks are there?
    - Igneous, metamorphic, sedimentary.
      - How each is formed. Field collecting.

- Fluorescence and phosphorescence.
  - Classroom and museum studies.
  - Use in prospecting for economic and strategic minerals.
- Study of weather and climate.
  - Climatic zones of our earth.
    - Map (Mercator projection) areas and boundaries.
  - Atmospheric pressure.
    - Use of barometers.
  - Variations in temperature.
    - Use of thermometers.
  - Relative humidity.
    - Rain, fog, "drying winds."
  - Wind direction and variation in intensity.
  - Cloud forms.
  - Hurricanes and tornadoes.
  - Weather maps.
    - How the weather bureau operates.
    - "Frost warnings" and "storm warnings."
      - Signals on land, on the ocean, and through the air.
    - Weather forecasting.
      - Work of "meteorologists" in peace and in war.
      - Weather stations and our national safety.

Unit III. "What Should We Know about Life on Our Earth?"

- Environment and its importance to living things.
  - Seasonal variation.
  - Ecological life zones.
    - Tangible and intangible barriers.
    - Aquatic life factors.
      - Fresh-water environment. Field studies.
      - Salt-water environment. Field studies.
      - Fresh- and salt-water movements (salmon, etc.).
      - Cold water as an influence on plant and animal life.
      - Warm water as an influence on plant and animal life.
      - Pollution of streams and tidewater as a factor.
    - Desert-life factors.
      - What the desert is like. Field work or pictures.
    - Swamp-life factors.
      - What swamps are like. Field work or pictures.

        Terrestrial-life factors. Field studies.
        Aerial-life factors.
            Air movements.
            Cold-air masses.
            Warm-air masses.
    Migration factors influencing movement of living things.
Plant life on our earth.
    Study of common local seed plants.
        Laboratory and field problems on seeds and seed dispersal.
        Laboratory and field problems on roots.
        Laboratory and field problems on stems.
        Laboratory and field problems on leaves.
        Laboratory and field problems on flowers.
        Laboratory and field problems on fruits.
    Study of plant economics.
        Which kinds of plants are important and why.
        Weeds. Field observations.
        Cultivation and breeding of desirable plants.
        Florists and nurseries. Class visits.
        Landscaping of parks and residential areas.
        The plant economics of recreational areas.
Animal life on our earth.
    Study of common local animals. Field observations.
    Study of animal economics.
        Which animals are important to each other, and why.
        Which animals are important to man, and why.
        Which animals are important to plants, and why.
Interdependence of living things.
    Parasitic plants and animals.
    "Partnership" plants and animals.
    The balance of nature.
How plants and animals live (general elementary survey only).
    Getting air. Comparison of plants and animals with humans.
    Getting food. Comparison of plants and animals with humans.
    Getting rid of waste. Comparison of plants and animals with humans.
    Moving about. Comparison of plants and animals with man.
    Response. Comparison of plants and animals with man.

- Reproducing. Comparison of plants and animals with man.
  - Emphasis upon the normal and natural in sex education.

Unit IV. "What Physical Factors Affect Life on Our Earth?"

- Survey of elements and compounds in nature.
  - Preview of the work of chemists and the field of chemistry.
  - Knowledge of the principal elements and common compounds.
- The basic element cycles in nature.
  - Nitrogen, carbon, and oxygen cycles and their importance.
- Air studies.
  - How the vacuum cleaner works.
  - Ventilation methods.
  - Heating and cooling systems and their operation.
  - Compressed air and its uses.
  - Airplanes and gliders.
    - The basic principles of flight.
      - Air resistance.
      - "Updrafts," "downdrafts," and "pockets."
    - Principles of modern jet propulsion.
      - Mechanics of jet flight.
  - Rocket missiles into air strata for scientific study.
  - Preview of the strategy of global air control.
    - In peace, rapid crop and human transportation.
    - In war, control of bombing and transport.
- Planetary astronomy.
  - Suns-stars concept.
  - The planets and their orbits.
    - Physical factors influencing possible planetary life.
  - What causes seasons on earth?
    - Hemispheric variation.
  - What causes tides?
  - Speed of light. The "light year" concept.
- Light.
  - The telescope. Historical development and modern use.
  - The microscope. Historical development and modern use.
  - How we "see."
    - Nearsightedness, farsightedness, astigmatism.
    - How "glasses" help when help is needed.

- The camera.
    - Comparison of the human eye with a camera.
    - How the camera works.
- Sound.
    - Speed of sound.
    - How we "hear."
        - Sound waves.
    - Sound recording and sound transmission.
        - How the phonograph works.
        - How the telephone works.
        - How sound movies are made.
- Radar and sonar.
    - Principles of radar operation.
        - Use in peace (ships) and war (airplane detection).
    - Principles of sonar operation.
        - Use in peace (fishing) and war (submarine detection).
- Heat.
    - Fire and its control for scientific use.
    - Steam engines and turbines.
        - How the locomotive works.
        - What makes the ocean liner go.
    - Internal combustion engines.
        - How the automobile engine works.
- Electricity.
    - How the electric light works.
    - How the electric heater works.
    - How the electric iron works.
    - How the electric refrigerator works.
    - What the telegraph and telephone wires can do.
        - Wonders of modern transmission. Importance to mankind.
- Radio.
    - How the radio studio operates.
        - Microphone.
        - Transmitter.
    - How the radio receiving set works.
    - Principles of television.
        - Rise of this modern phase of radio.
        - Problems of production, transmission, and reception.

- Energy in nature.
  - Structure and occurrence of atoms and molecules.
    - Protons and their importance.
    - Electrons and their importance.
    - Neutrons and their importance.
  - The general principle of energy conservation.
  - Ideas of fission and radiation.
  - Concepts of atomic uses in peace as well as in war.
  - Outline of how an atomic bomb works.
  - What to do if an atomic bomb falls in the community.

Unit V. "How May We Control Our Environment?"

- Principles of conservation of natural resources.
- Why people live where they live.
  - Elements of sociology. Wise use of environment.
- Principles of collective health supervision and control.
  - Government, state, county, and city health administration.
  - Cooperation of each citizen. Careful voting in the future.
- Work of great scientists of the past.
  - Achievements in environmental control.
- Opportunities for scientists of the future.
  - Study, research, and experiment to make a better world.
- Fields of scientific study and opportunity.
  - Preview survey of biological science courses in the high school.
  - Preview survey of physical science courses in the high school.
- How each student may control his own life environment.
  - Lifework choices in home, community, and education.

PROBLEMS FOR GROUP DISCUSSION AND REVIEW

1. Discuss the relative position of "general" science in the secondary school curriculum.
2. What do you consider to be valid basic objectives of a survey course in general science, in terms of general education?
3. What sociological factors are involved in teaching ninth-grade science?
4. What psychological factors are involved?

5. To what extent should the science teacher undertake guidance of adolescents in terms of character education? Are morals and character the "business" of science teachers?
6. What are your opinions on sex education? To what extent are you in agreement with the recommendations of the text with regard to this problem?
7. Discuss the proper use of the demonstration method.
8. What are the virtues of the individual and group experimental method?
9. Employing the type presentation of the basic element cycles in nature as a basis for criticism, discuss in terms of (*a*) approach, (*b*) content coverage of related science and social science fields, and (*c*) application to life.
10. Outline the content and subject sequence *you* consider essential in the general science survey course.

Chapter 4. GENERAL BIOLOGY

A study of biological instruction at secondary school level discloses at once two rather divergent concepts as to method. It is as if rival schools of thought have graduated teachers, each of whom, with unswerving loyalty, clings to those tenets sponsored by his alma mater. In discussion groups, in departmental faculty meetings, at institutes, wherever high school biology teachers gather, "systematists" oppose "physiologists" or "functionists." Each group seems certain of the soundness of its principles and equally positive of the fallacy of the opposing viewpoint.

It will become evident as our survey progresses that the term "physiologist" as applied to secondary school instructional method, is quite dissimilar from the university-type physiological concepts of laboratory instruction, for analytical procedures with emphasis upon cellular physiology as stressed in many institutions of higher learning today can scarcely be put into practice in junior and senior high school classrooms. Training for analytical research must remain the province of the college and the university; our discussion properly concerns itself with secondary instructional viewpoints.

Systematist

In brief, the one group holds that the logical approach to understanding of biology is through systematic study of various forms, beginning with the simpler organisms and proceeding in orderly sequence to the more complex. Each of the more important plant and animal phyla are studied in turn; all facts bearing upon each organism being studied are brought to bear at one time. Structure, habitat, method of getting food, method of getting air, method of receiving or responding to sensations, method of moving about, means of protection from enemies, and reproduction are taken up while specimens are actually before the student.

Ecological relationships and economic importance are given a perspective quality not easily attainable by a strictly functional method of attack. Further, the claim is made that purely functional teaching, as presented below, presupposes a structural background which adolescent children do not possess. The structuralist-systematist rests his case with the assertion that his method gives the secondary student a broader conception of man's relative importance in the scheme of things than he could obtain otherwise.

Functionist

To all this the "functionist" replies that acquaintance with the morphology and taxonomy of a large number of organisms is not of basic importance to students of early secondary grade, but rather constitutes a field for advanced students of botany and zoology in the later years of high school and in the college or university. Fifteen-year-olds are not interested in taxonomical *which* and *why*. They want to know *what* living things do, and *how* they do them. Most of all they ask: "What of it? What has that to do with *me?*" And herein lies the essential worth of the functional method of presentation. Man is constantly in the foreground. His relations with other animals and with plants are brought out in every lesson. Instead of students' having to wait until the last part of a year's course to study the biology of man, this most interesting and educationally important phase is continually under investigation. Results claimed by proponents are these: a more sustained interest throughout the course, a better understanding of interrelationships of organisms and the perfection of nature's balance, as well as a more complete realization of the vast complexity of the living world.

Evaluation

In spite of many years' controversy, each of the two basic groups at present clings tenaciously to its philosophy, holding the other to be basically in error. That this apparent pedagogical deadlock has existed and still exists throughout the country will readily be admitted by those conversant with the situation on the "firing line" of high school biology. Seemingly irreconcilable, advocates of these trends of thought have so far resisted arbitration.

As a matter of fact, however, these viewpoints do not differ so widely as first glance might indicate. Each teaches a love of nature and a respect for her laws. Each strives to impart as broad a knowledge of biology as possible, commensurate with the age level and general intellectual ability of the pupils concerned. The great basic aim of biology teaching in the ninth or the tenth grade must be to supply foundational knowledge, which may be brought into play through the study of applications in social biology or other sciences studied later in the curriculum.[1] Such primary effort being characteristic of general biology teachers everywhere, any measurement of assimilation which is reliable and valid should reveal approximately equal attainment at the end of each school term.[2] Fundamentally, then, major objectives are similar, the primary difference being in philosophy of method.

[1] Riddle, Oscar, "Amount and Nature of Biology Teaching in Secondary Schools," *The Teaching of Biology in Secondary Schools of the United States*, Committee on the Teaching of Biology of the Union of American Biological Societies, 1942.

[2] For exemplary standardized instruments see Chap. 10, Evaluation and Diagnosis.

Combination Plan

Each group sincerely believes that its method possesses advantages which are unique. In this each is correct, as a review of the points mentioned will substantiate. Then why not teach by *both* methods? Why not apply what seems best in each? If it is true that pupils come into the ninth- or the tenth-grade biology laboratory without a structural background necessary to an understanding of functions, why not give them this foundation, early in the course? Is it not reasonable to assume that a student will more readily grasp the broad concept of respiration, for instance, if he knows the general structure and location of stomates, lenticels, gills, spiracles, and lungs in the various plant and animal forms than if he has to interrupt the assimilative process in order to ferret out each in turn?

Several years of secondary school class observation and experiment have convinced the author of the soundness of this pyramid theory. We have taught high school classes according to the systematic structural viewpoint, and we have taught classes according to the functional life-process method. We have combined the two, in practice. It has been our observation over an extended period of years, that all groups, whether segregated according to sex, intelligence quotient, or social maturity, or mixed without regard to these factors, react best to a systematic structural foundation leading to generalizations regarding the study of functions, processes, and basic principles. The author is convinced that this combination method excels either of the others in establishing a foundation for conclusive scientific reasoning and in developing a well-balanced attitude.

The following outlines are included at this point as being illustrative of the three methods of approach.[3] They represent course plans designed by the author, and used in actual instruction of ninth- and tenth-grade students over a considerable period. It is understood, of course, that these outlines are purely suggestive in nature, permitting of wide variation from pattern.[4]

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[3] A fourth method, the *human* or *social* approach, will be described separately in the next chapter.

COURSE A: SYSTEMATIC BIOLOGY

Unit I. "What Is Biology?"
  The study of living things: bios, logos.
  Summary of the history of biological science.

Unit II. "What Is the Nature of Our World?"
  Nonliving and living things.
  Overview of environmental factors.
    Elements and compounds in nature. Matter and energy.
  Protoplasm and the cell.
    Importance of cells in modern biology.
    Basic differences between plant and animal cells.

Unit III. "Plant Biology."
  What should we know about plants?
    Habitat.
    Structure.
    Physiology.
    Economic importance.
  Problems and projects on soils as related to plant growth.
  Problems and projects on seeds.
  Problems and projects on roots.
  Problems and projects on stems.
  Problems and projects on leaves.
  Problems and projects on flowers.
  Problems and projects on fruits.
  Plant classification.
  Algae and fungi (economic types).
  Liverworts and mosses.

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[4] Should the student teacher desire to examine complete courses of study such as are in practical use in all the principal cities, notes addressed in each case to the *Bureau of Curriculum* will bring price lists of available printed material. In this way a comparative study may be made, with the selection and arrangement of subject content according to individual need and preference.

- Ferns and their relatives.
- Geographic isolation and distribution.
- Ecological factors influencing plant life.
  - Tangible and intangible barriers.
- Plant behavior (tropisms).
- Plant breeding (applied elementary plant genetics).

Unit IV. "Animal Biology."

- What should we know about animals?
  - Structure.
  - Physiology.
  - Habitat.
  - Geographical isolation and distribution.
  - Ecological factors influencing animals.
  - Behavior, including mimicry.
  - Methods of reproduction.
  - Animal economics.
- Animal classification.
- Problems and projects on protozoa.
- Problems and projects on sponges.
- Problems and projects on coelenterates.
- Problems and projects on worms.
- Problems and projects on echinoderms.
- Problems and projects on mollusks.
- Problems and projects on arthropods.
- Problems and projects on sharks and fishes.
- Problems and projects on amphibians.
- Problems and projects on reptiles.
- Problems and projects on birds.
- Problems and projects on mammals.

Unit V. "Human Biology."

- General gross human anatomy.
- General elementary human physiology.
- Essentials of personal and community hygiene.
  - Physiology and hygiene of human nutrition.
  - Physiology and hygiene of human respiration.
  - Physiology and hygiene of human excretion.
  - Cleanliness at home, at school, and in the community.
- Problems and projects on alcohol, tobacco, and common narcotic drugs.

- Problems and projects on reproduction.
  - Summary of plant reproduction.
  - Summary of lower invertebrate reproduction.
  - Summary of lower vertebrate reproduction.
  - Reproduction in the human animal.
- How may we improve human environment?
  - Problems and projects on soil and agricultural production.
  - Problems and projects on conservation of natural resources.
  - Science problems in home and community.
  - Science problems in industry.
- How may we improve ourselves?
  - Euthenics (war among men, poverty, immigration, and other factors).
  - Eugenics (marriage and the family).

COURSE B: FUNCTIONAL BIOLOGY

Unit I. "What Is Biology?"
- The study of living things: bios, logos.
- Summary of the history of biological science.

Unit II. "What Is the Nature of Our World?"
- Nonliving and living things.
- Necessities for life on earth.
  - Air, food, water, and warmth (for bird and mammalian animal life).

Unit III. "How Are Living Things Interrelated?"
- Protoplasm and the cellular concept.
- Problems and projects on unicellular life (plant and animal).
- Problems and projects on photosynthesis.
  - Plant-animal interdependence.
- Problems and projects on comparative life histories (plant and animal).
- Problems and projects on metamorphosis.

Unit IV. "What Processes Are Carried on by All Living Things?"
- *Respiration.* Problems, projects, and reports, including the following:
  - How plants get air. Stomate structure and functioning in leaves.

Stem lenticel structure. Root air absorption.
Insect spiracles and tracheae.
Fish gills.
Amphibian tadpole respiration. Amphibian adult respiration.
Reptilian, bird, and human respiration.

Nutrition. Problems, projects, and reports, including the following:

Food manufacture in photosynthetic plants.
Plant digestion, tissue distribution, and cellular assimilation.
Lower animal digestive systems, such as the earthworm and the shark.
  Comparative anatomy: typhlosole, spiral valve, etc.
Digestion and assimilation in the human animal.

Circulation. Problems, projects, and reports, including the following:

Movement of fluids in plant xylem and phloem tubes.
Fish circulation (heart of one auricle and one ventricle).
Amphibian circulation (heart auricular change during metamorphosis).
Reptilian circulation (typically two auricles, one ventricle).
Bird and human pulmonary circulation (two auricles, two ventricles).
Human blood and blood plasma. Leukocytes and erythrocytes.

Excretion. Problems, projects, and reports, including the following:

Plant excretions (gums, resins).
Invertebrate-animal excretory systems (earthworm, crayfish).
Vertebrate-animal excretory systems. Human excretory organs and system.

Response to Sensation. Problems, projects, and reports, including the following:

Plant reactions to external stimuli (tropisms).
Invertebrate and lower vertebrate responses.
Human sense organs and responses. Reflex actions.

Motion. Problems, projects, and reports, including the following:

Protoplasmic flow. Observation in plant cells.

Ameboid, ciliary, flagellate, and muscular unicellular types. *Ameba, Paramecium, Euglena,* and *Vorticella* as examples.

Plant movement; motion and locomotion. Tropisms. Slime molds.

Invertebrate animal motion.

Vertebrate animal motion, including movements of man.

Growth. Problems, projects, and reports, including the following:

Plant-seed germination and seedling growth.

Effect of light as it inhibits growth and influences direction.

Cambium functioning. Formation of annual rings in tree stems.

Plant and animal cell division (mitosis).

Regeneration of lost parts (*Hydra,* crab, flatworm, starfish).

Reproduction. Problems, projects, and reports, including the following:

Pollination and fertilization in seed plants.

Seed dispersal methods and modifications.

"Slipping" and grafting techniques.

Tubers, bulbs, and runners. Stem propagation.

Spore reproduction in lower plants.

Alternation of generation cycles in liverworts, mosses, ferns.

Alternation of generation cycles in animal forms such as *Obelia.*

Sperm and egg cells in vertebrate animals.

The biology of human reproduction.

Unit V. "How May Living Things Keep Healthy?"

The hygiene of respiration.

How living things get air. How human animals breathe.

Ventilation, air conditioning. Oxygenation of aquatic habitat.

Artificial resuscitation in cases of drowning or shock.

The hygiene of nutrition.

How living things get food; survey from *Amoeba* to man.

What we should eat, how much, when, and why.

The hygiene of circulation.

Review of comparative anatomy of circulatory systems.

Human circulation. Exercise and "keeping fit." Heart hygiene.

- The hygiene of excretion.
  - Review of the comparative anatomy of excretory systems.
  - Human excretion; care of the intestines, kidneys, skin, and lungs.
- The hygiene of the nervous system.
  - Review of the comparative anatomy of nervous systems.
  - Special senses, instincts, and habit formation.
  - Mental hygiene. Psychosomatic medicine.

Unit VI. "How May Living Things Be Improved?"
- Control of plant and animal environment.
  - Review of factors influencing life and living. Euthenics.
- Control of heredity.
  - Principles of plant and animal breeding. Genetics.
  - Human factors. Marriage and the family.

COURSE C: COMBINATION METHOD

Unit I. "What Is Biology?"
- The study of living things: bios, logos.
- Summary of the history of biological science.

Unit II. "What Is the Nature of Our World?"
- Nonliving and living things.
- Overview of environmental factors.
  - Elements and compounds in nature. Matter, energy, and life.
- Preliminary survey of familiar plants and animals.
  - Where and how living things live.
- Protoplasm and the cellular concept.
  - Plant and animal bodies composed of cells and tissues.
  - Importance of cells in modern biology.
  - Basic differences between plant and animal cells.

Unit III. "What Is the Structure of a Typical 'Seed' Plant?"
- Flowers (field observation and laboratory examination).
- Fruits (field observation and laboratory examination).
- Seeds (field observation and laboratory examination).
- Roots (field observation and laboratory examination).
- Stems (field observation and laboratory examination).
- Leaves (field observation and laboratory examination).

Unit IV. "What Kinds of Plants Are There?" (Progressive development from the known to the unknown.)

- Spermatophytes.
  - Seed plants. General structure and occurrence.
    - Gymnosperms ("polycots").
    - Angiosperms ("monocots" and "dicots").
- Pteridophytes.
  - Ferns. General structure and occurrence.
- Bryophytes.
  - Mosses and liverworts. General structure and occurrence.
- Thallophytes.
  - Fresh- and salt-water algae. General structure and occurrence. Types.
  - Fungi. General structure and occurrence. Preview of economics. Types.
  - Lichens. General structure and occurrence. Types.

Unit V. "What Kinds of Animals Are There?" (Progressive development from the known to the unknown.)

- *Vertebrates.*
  - Mammals.
    - Study general form of each mammal selected for study.
    - Collect pictures illustrative of color, size, and environment.
    - Obtain informative data on the relation of each mammalian type to man, the supreme mammal.
    - Study oriented informally as follows:
      - Group 1: Familiar mammals. Dog, cat, rat, sheep, pig, cow, horse, donkey, deer, squirrel, chipmunk, skunk, coyote, rabbit.
      - Group 2: Mammals we see in the circus or zoo. Camel, giraffe, fox, wolf, tiger, bear, lion, gazelle, bison, zebra, sea lion, rhinoceros, hippopotamus, kangaroo, elephant, monkey, baboon, ape, gorilla.
      - Group 3: Mammals we read about but do not often see. Armadillo, whale, dolphin, porpoise, walrus, anteater, sloth, duck-billed platypus.
  - Birds.
    - Study general form of each bird selected for study.
    - Collect pictures illustrative of color, size, and environment.

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  -
    - Emphasize local bird neighbors. Make field trips to observe groups of birds in their native habitat, including nests.
    - Ecological groups: marine, marsh, desert, and mountain birds.
    - Emphasize protective coloration and seasonal change.
  - Reptiles.
    - Prehistoric reptiles, such as dinosaurs, which students have read about and seen in the "movies," studied for motivation.
    - Modern reptilian forms: Snakes lizards, turtles, crocodiles, and alligators.
      - General form, color, and habitat. Ecology.
  - Amphibians.
    - Salamanders, newts, frogs, and toads.
      - General form, color, habitat. General ecology.
      - Life history of the common grass frog as a type.
  - Fishes.
    - Fresh-water fish types. General form, color, habits.
    - Salt-water fish types. General form, color, habits.
      - Life history of the salmon as a study in fish ecology.
      - Emphasize that "cold-blooded" actually means *adaptable.*

- *Invertebrates.*
  - Insects.
    - Characteristics of a typical insect.
    - General external structure of a grasshopper as a type.
    - Life history of an insect, showing metamorphosis (silk moth).
    - Protective coloration and mimicry among insects (dead-leaf butterfly).
    - Emphasis upon the social insects, such as the bees, ants, and termites.
    - Survey of insect orders of outstanding importance in nature.
    - Entomology as an important branch of general biology.
  - Arachnids.
    - What are spiders, mites, and ticks? What do they look like and where do they live? In what ways are they important?

  - Why the spider is not an insect.
  - Poisonous and nonpoisonous spiders. Type study.
  - The scorpion and the horseshoe "crab" of New England. Type study.
- Myriapods.
  - Centipedes and millipedes. Type study and general ecology.
- Worms.
  - The three important worm groups (flatworms, roundworms, segmented worms).
    - Type studies in each group. General form and occurrence.
    - Preview of economically important types.
  - The earthworm as a general-type common segmented worm.
- Crustaceans.
  - Fresh-water type: crayfish. Structure, habitat, importance.
  - Salt-water types: Crab, lobster, shrimp, barnacle.
- Mollusks.
  - Terrestrial type: garden snail. Structure, habitat, importance.
  - Fresh-water type: river clam. Structure, habitat, importance.
  - Salt-water types: mussel, clam, scallop, abalone.
- Echinoderms.
  - Starfishes. Structure, habitat, importance. Strange ecology.
  - Sea urchins and sand dollars. Structure, habitat, ecology.
  - Sea cucumbers. Structure, habitat, strange ecology, importance.
- Coelenterates.
  - Fresh-water type: *Hydra*. Structure, habitat, ecology.
  - Salt-water types: Sea anemones, corals, jellyfishes.
- Sponges.
  - Where and how sponges grow. Why sponges are animals.
- Protozoa.
  - The place of unicellular animals in the living world.
  - Type study of such forms as *Amoeba, Paramecium, Euglena, Vorticella.*

Unit VI. "How Is Life Maintained?"
- A comparative study of plant and animal systems and their functioning.
  - Respiration (getting air) in plants and animals.
  - Nutrition (getting food) in plants and animals.
  - Excretion (getting rid of waste) in plants and animals.
  - Motion (including locomotion) in plants and animals.
  - Circulation (fluid movement) in plants and animals.
  - Growth and reproduction in plants and animals.

Unit VII. "In What Ways Do Living Things Respond to Stimuli?"
- Behavior of living things as a field of study. Human psychology.
- Protective plant and animal reactions.
- Tropisms in plants and in lower invertebrates.
- Coloration, including mimicry and aggressive warning in nature.
- The special senses in vertebrates, including man.
- Reflex actions. Habit formation.

Unit VIII. "In What Ways Are Living Things Interdependent?"
- Variations in ecology. Dwellers of the sea, fresh-water streams and lakes, swamps, deserts, mountains, plains, Arctic and Antarctic, subtropical and tropical areas of the earth.
- Adaptive structure and adaptive habit.
- Interdependence as shown by yucca plant—yucca moth and others.
- Parasitism, saprophytism, commensalism, symbiosis.
- Balance of life throughout nature. The balanced aquarium as a unit.

Unit IX. "How Do Living Things Affect Human Welfare?"
- *Plants.*
  - Economic aspects of plant life.
    - Photosynthesis, a biological necessity. Food manufacture for photosynthetic plants; food for parasitic plants; food for animal life. End-product oxygen put into air and into water.
    - Field and tree crops.
      - Fruits: Apples, pears, peaches, olives, oranges, lemons, melons, walnuts, Brazil nuts, almonds, coconuts.

- Seeds: Beans, peas, castor beans, rice, wheat, corn, oats, cotton, coffee, mustard.
- Roots: Beets, carrots, turnips, parsnips, licorice.
- Stems: Cane and maple sugars, asparagus, cinnamon, camphor, tubers (potato, onion).
- Leaves: Lettuce, cabbage, kale, broccoli, parsley, mint, bay, tea, tobacco.

Agricultural and horticultural factors.
- Soil textures, composition, acidity, fertilizer types.
- Field soil practices. Plowing, harrowing, burning, terracing, contouring.
- Field irrigation practices. Ditches, pumps, overhead sprinkling.
- Crop rotation principles.
- Pruning times and techniques.
- Spraying and painting of insecticides and fungicides.

Spore plants.
- Mildews, yeasts, mushrooms, rusts, blights, harmful and beneficial bacteria. Laboratory and field studies.

Nursery plants.
- Flowers and flowering plants as commercial properties.
  - Nursery stock; garden and field plants. Seeds.
  - Commercial seed farms; commercial flower farms.

Forest plants.
- Deciduous and coniferous forest areas of the United States.
- Lumber and the lumbering industry.
- The paper and paper-pulp industries.
- Wood "wool" and other insulation industries.
- Maple sugar and its production.
- Natural rubber and its production.
- Turpentine and its production.
- Indirect values of forested lands.
  - Erosion control, flood control, climatic effects, soil creation, homes for animal life, recreational areas.

Aesthetic aspects of plant life.
- Seed plants.
  - Grasses, lilies, palms, and other monocot plants used.
  - Roses, dahlias, marigolds, and similar composites.

- Seed plants as lures for bird life.
- Field flower collecting for aesthetic appreciation.

Plants without seeds.
- Ferns, mosses.
- Algae. "Seaweed" collecting and mounting.

Home gardening.
- Flowers, vegetables, lawns, shrubs, trees.

City and county parks.
- Landscaping for aesthetic appreciation.

National parks, forests, and monuments.

State parks. Recreation for all the people.

Animals.

- Invertebrate animals of economic importance to man.
  - Unicellular animals.
    - Economic uses in industry.
    - Relationship to disease, such as malaria.
    - Part of the "plankton" food for animal life.
  - Sponges.
    - The sponge industry in Greece and in Florida.
  - Coelenterates.
    - Coral reefs; coral islands. Commercial corals.
  - Worms.
    - The earthworm and its biological significance.
    - Parasitic flatworms (liver fluke and tapeworm).
    - Parasitic roundworms (hookworm and intestinal roundworm).
  - Mollusks.
    - Clams, oysters, scallops, and other edible forms.
    - Pearl formation and the pearl industry.
    - Shell ornament and button industries.
    - Terrestrial garden snails and their economic importance.
    - Edible snails, such as the "escargots" of France.
    - The "shipworm" or *Teredo.*
  - Echinoderms.
    - Starfishes as a menace to oyster beds.
    - Trepang, or *bêche-de-mer,* as a world food.
  - Crustaceans.
    - Food crustaceans: lobsters, crabs, prawns, shrimps, crayfish.

- Barnacles and their economic harm to ships. Prevention methods.

- Insects.
  - Beneficial forms: bees, silk moths, dragonflies, "ladybugs."
    - Insects as cross-pollinators of flowering plants.
  - Harmful forms: flies, fleas, ants, termites, mosquitoes, scale insects, clothing-moth larvae, aphids, locusts.
  - Insects and disease. Control of disease-transmitting forms.
- Arachnids.
  - Menace of some mites and ticks to health.
  - Beneficial spiders.
  - The "black widow" as an American poisonous type.

Vertebrate animals of economic importance.

- Sharks and fishes.
  - Food and vitamin A extraction from livers of some types.
  - Fertilizers, canned dog and cat food, sport fishing.
  - Extent and importance of the fishing industry.
- Amphibians.
  - The toad as the "gardener's friend."
  - Frog legs as epicurean food.
  - Frog "farms" for commercial biological supply firms.
- Reptiles.
- Lizards, snakes, and alligators as sources of leather.
  - Poisonous forms (world and the United States).
  - Beneficial forms (world and the United States).
- Birds.[5]
  - Food for man: chickens, ducks, geese, turkeys, doves, quail.
  - Songbirds and bird pets: canaries, meadowlarks, love birds, thrushes, nightingales, mockingbirds.
  - Harmful field forms.
    - Study of some hawks, crows, sparrows, and jays.
    - Identification of harmful birds.

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[5] For exemplary reference material to be used in connection with this phase of study see: Collins, Stephen, *Hunters and Hunted,* Cornell Rural School Leaflet, Vol. 43, No. 3, Winter 1949–1950, New York State College of Agriculture, Cornell University, Ithaca, N.Y., 1950.

- Beneficial field forms.
    - Study of helpful birds and why they are protected.
        - Gulls, buzzards, bobolinks, roadrunners.
    - Use of feathers for millinery and for pillows. Geese, egrets, glossy ibises, ostriches.
- Mammals.
    - Follow the form previously developed in type study (Unit V).
    - Tabulation and summary of economically important mammals.

Unit X. "How May Living Things Be Improved?"
- Control of environment.
    - Sanitation and public health.
    - Community cooperation and group health services.
    - First aid (burns, shock, suffocation, drowning).
    - Hospitals, clinics, and their work.[6]
    - City planning (zoning, traffic control in accident prevention, and community landscaping of parks, parkways, and boulevards).
    - Home planning (gardening, health measures, safety, beautification).
- Control of heredity.
    - Plant- and animal-breeding principles (applied genetics).
    - Eugenics and euthenics.[7]
        - Immigration, poverty, human inheritance, hereditary factors (such as Rh factor), war and its effect on human welfare.

AIMS

Whatever the method, ultimate objectives should be the same. Secondary school environmental general biology should develop standards of physical and mental health. First aid, sanitation, personal grooming, the cultivation of plants and their appreciation, the laws of inheritance, a knowledge of animal life, and similar presentations will prepare for worthy home membership and parenthood in our democratic society. Discussion of natural resources, conservation, and public health services, together with valid biological reasons for continued world peace attempts and the eventual outlawing of international warfare, will lay solid foundations for good citizenship and the world viewpoint so essential in the troubled, socially upset world environment of today.[8]

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[6] Laird, Thelma F., "Professional Nursing as a Career," *Bios*, Vol. XVIII, No. 3, October, 1947.

[7] Robertson, G. Gordon, "Medical Genetics," *Bios*, Vol. XX, No. 5, October, 1949.

SEQUENCE

One distinctive feature of the courses of study presented in this chapter has doubtless caused comment: namely, the organization of topics in plant and animal survey (Units III, IV, and V) of the "combination"-plan course outline in general life science. The radical departure from the traditional approach, which begins such a course with the "simplest" forms and progresses toward the "most complex," has been taken with deliberation. The instructor, standing at or near the end of his formal training in this field, has hitherto presented what *seemed* fundamental and easiest first, leading up to what *he* considered to be more intricate as the climax period of the term was reached.

Morphologically and physiologically the instructor has been technically correct; psychologically he has been markedly in error. His students as they come to him in junior or senior high school frequently do not know a paramecium from a pancreas. They are more or less familiar with trees, flowers, and the general external structure of some plants, as well as with horses, cows, sheep, dogs, cats, rabbits, birds, and a few of the more common local insects, but they have hazy impressions indeed of such items as liverworts, algae, hydroids, and protozoans. Should any teacher thrust this subject material, involving not only microscopical drawings, manipulative techniques, and life-cycle studies, but a varied natural-history background for successful work, upon his charges during the opening weeks of a course in ninth- or tenth-grade life science? The answer is obvious; the wonder of it is that we have delayed so long in applying common sense (under the guise of psychological analysis) to such a fundamental situation.

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[8] Henderson, A. D., "Education for Today," *Child Study*, Vol. XXVIII, No. 3, Summer, 1950.

From Known to Unknown

The socialized classroom solves many of these problems, for here the boys and girls debate issues, select their own problems, and choose their own references.[9] Let us resolve to begin our studies with those subjects found to be more familiar *to our students,* organizing the subject matter in such a way that they will be led to contribute what they have already learned, thus developing confidence in their own ability to seek out new facts in this strange and fascinating subject which deals with living things. A preliminary survey of history [10] shows correlation with the social sciences, demonstrates progress, and stimulates an attitude of respect toward the development of the scientific method. The outline-type survey provides a knowledge of structure, giving students a framework upon which the superstructure of principles and their applications may be built. That this solid foundation be structurally designed *from the viewpoint of the high school sophomore* [11] rather than from that of the graduate systematist is of utmost significance in our survey of optimum procedures.[12]

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[9] Knepp, Thomas H., "The Reading Choices of High School Biology Students," *Turtox News,* Vol. 28, No. 8, August, 1950.

[10] For exemplary use refer to Chap. 2, Science and the Scientific Method.

[11] Packard, Charles E., "What Biological Facts Interest High School Sophomores?" *The American Biology Teacher,* Vol. 9, No. 2, November, 194[illegible].

[12] Packard, Charles E., "The Five Best Remembered Plant Facts," *The American Biology Teacher,* Vol. 10, No. 8, December, 1948.

CONSERVATION EDUCATION IN THE HIGH SCHOOL

There has been a marked increase in the amount of teaching time devoted to the subject of conservation of natural resources in recent years, and a consequent realization upon the part of socially minded investigators of the part played by conservation in citizenship training in our democracy.[13] Many of our more progressive state departments of education have devoted research and supervisory time to cooperation with national and state agencies in the preparation of adequate instructional materials and programs.[14] The feeling is general that conservation education should be a *continuous* process, building through the upper elementary grades toward culmination in the high school general and college-preparatory classes, or in social biology as described in the chapter which follows. Such topics as erosion, fire prevention, tree preservation (from an aesthetic viewpoint as well as from that of a water-conserving measure), protection of wild flowers in the open and in domestic parks and gardens will be brought out during the year's study. Observance of state fish and game laws, participation in campaigns against crop-destroying insects and plant parasites, roadside-beautification measures, home and school garden planning, respectful care and appreciation of recreational areas, establishment of a "Use without Waste" philosophy in dealing with natural resources such as water, together with measures designed to further the conservation of human health and energy, comprise stimulative unit investigation topics.

The great nationwide system of interlocking roads and superhighways furnishes incentive to a consideration of roadside beautification as a constructive phase of conservation education. Local roads within the county may be made the subject of committee investigations, projects for improvement fitting naturally into such a program. The general theme should center upon elimination of unsightliness of whatever type: commercial signs, rubbish piles, neighborhood dumps, etc. The forward-looking teacher will visualize the possibilities inherent in the education of young people along lines tending toward better citizenship in a democracy.[15] His charges will one day be active, traveling, voting citizens of the commonwealth. "As the twig is bent, so is the tree inclined." [16]

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[13] Report of the Eagle River Workshop Conference, *Training Teachers for Conservation Education*, National Committee on Policies in Conservation Education, Laramie, Wyo., 1949.

[14] For example, *Guidebook for Conservation Education, a Proposal for a Program of Action in the Schools of California*, published by the State Department of Natural Resources, in cooperation with the State Department of Education, Sacramento, 1950.

Arbor Day

Community observance of Arbor Day is notable throughout the nation. Exercises within the school grounds may be supplemented by dramatic presentations in very effective fashion in terms of impressions upon the thinking of young students. That most effective instrument, the dramatic playlet, may be employed to advantage; one prepared under supervision of the author will illustrate.

ARBOR DAY PLAYLET

Presented by Grade 9A biology class.
Presentation time: Forty minutes.

Program:

I. Introduction.
II. Tree Planting Demonstration.
III. Garden Planting Demonstration.
IV. Musical Intermission.
V. Flowering Garden Scene.
VI. Identification of Flowering Plants.

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[15] Thut, I. N., and Gerberich, J. R., *Foundations of Method for Secondary Schools,* McGraw-Hill Book Company, Inc., New York, 1949.

[16] Renner, George T., "Teach Americans to Conserve Resources," *The Phi Delta Kappan,* Vol. XXXI, No. 4, December, 1949.

Action:

I. Introduction: A brief talk on the origin and purpose of Arbor Day given by a 9A student in front of the stage curtain.

II. Tree Planting (by four 9A boys).

Setting: One corner of the garden plot. This plot, eight by ten feet, was created in the center of the stage by placing sandy-loam soil 6 inches deep over the entire area. The stage floor was protected by heavy canvas and the soil was retained by 1- by 6-inch redwood boards at the back and ends. The front edge of the plot was open and sloped toward the audience, large rocks holding the end boards from spreading.

Action: Three boys enter the stage; one carrying a tree in a gallon container, another a shovel, and the third a pair of tin shears. A fourth boy enters from the opposite side of the stage and asks questions to bring out the various steps of correct procedure in planting a tree.

The boy with the shovel digs a hole, telling the size and depth of the hole necessary.

The boy carrying the tree removes the can and plants the tree, explaining each act as it is performed. *Curtain.*

III. Garden Planting Demonstration (by 9A boys).

Setting: Same garden plot as for Tree Planting. Plot is covered with tin cans, bottles, and rubbish.

Action: Entire garden class enters to inspect and make remarks about the untidiness of the scene. One member suggests going into the junk business, another suggests making a garden. All agree to last suggestion, some going offstage to obtain tools and wheelbarrow. (All help to clean plot except the one who suggested going into the junk business and his pal. These two boys remain on stage during the entire act to ask key questions about the succeeding operations. They also form a continuity of action through gossip about the school and well-known personalities.)

After the plot is cleaned up all exit except the two mentioned.

Two boys then enter and cultivate the plot thoroughly, answering the questions of the comedy pair, and then exit. Two other boys enter with rakes and smooth up the plot, also bantering with the comedy pair. A third pair of boys enter with stakes, garden line, and small trowels, measuring and marking out rows and answering questions about depth of furrow, distance between rows, etc.

The fourth pair of boys enter with seed, each telling what he is going to plant and why. They are followed by a boy with a bucket of sand to cover the seed, and a boy with a sprinkling can to water the plot. Each one defends his task by logical remarks to the comedy pair. *Curtain.*

IV. Musical Intermission.

V. Flowering Garden Scene.

Setting: Garden plot as before. During the intermission potted flowering plants from the school glass house were placed on the plot. These in the first two rows were plunged slightly into soil and the higher plants were placed at the back to give graduated height effect. Raffia mats, borrowed from a local florist, were used to produce a turf effect at front and sides, while small potted trees furnished a background. Forty-five *Primula* were used in the front five rows, and twenty-seven *Cineraria* of graduated height were used in the three rear rows.

Action: Most of the 9A class enter and make admiring remarks about the improvement from trash heap to blooming garden. (The two comedy members stress very loudly their important part in its making.)

All retire to rear and remain on stage for flower identification.

VI. Flower Identification.

Setting: Continuation of above scene.

Action: Six members of the 9A class enter, one at a time, each with a potted flowering plant, and hold it before the audience. Each gives the name, colors, habitat, and a few simple cultural directions for the flower he represents, and then retires to the rear of the garden plot.[17]

VII. Finale: Choric verse on *Conservation. Final curtain.*

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[17] Flowers used by the author in developing this ninth-grade presentation were *Cineraria, Calendula, Clarkia, Primula,* and varied stocks. Backgrounds were of mock orange branches (*Pittosporum undulatum*) and Monterey cypress (*Cupressus macrocarpa*).

NATURE TRAILS IN THE SECONDARY SCHOOL SCIENCE PROGRAM

The establishment of one or more "nature trails" as advocated by many conservation organizations makes an admirable high school student project and may, indeed, be developed from year to year as a continuous group endeavor. Such a trail need not be very long, nor should it be located at too great a distance from the school grounds; rather, it should be planned with reference to accessibility and functional use. An inviting path may be laid out by one group, not so wide as to convey a sense of artificiality, but rather to convey the mood of exploration, to study nature as it is.

Another group may label as to common name and genus, attention being focused upon the largest and most prominent forms, then centered on new plants and natural objects as study advances. Not only plant life, but rocks, peculiar formations, and interesting ecological situations may be indicated. There is much biology in any small wooded area; the scope and financial outlay need not be excessive.

Questions and stimulative problems may be added to the explanatory labeling and thus a veritable game may be made of the learning process. Students should be trained to be on the alert for animal tracks,[18] for other than human animals will walk this path! Any bit of wooded land, thicket, or shady dell, will serve for such a trail in the country, but in urban areas the city parks must usually suffice. These may not be cut into or otherwise altered, but permission for considerate use and group labeling may usually be secured without difficulty from the city parks superintendent.

FIELD WORK

In addition to the recommended nature trails utilized in the immediate vicinity of the school, do not overlook actual field expeditions to points of interest in and about the community. A museum, zoo, botanic garden, natural pond, creek, or seashore excursion is worth any expenditure of time and trouble. Indeed, how many of *your* high school students have ever visited a dairy? How many metropolitan boys and girls have actually been guided through the American Museum of Natural History by a competent biologist? What happens to city garbage? How many pupils have ever visited the early-morning fruit and produce markets? What happens to a fish after it has been caught commercially? These and many other questions should provide stimulative answers in the minds of junior and senior high school teachers in comparable situations throughout the country. The ancient Chinese proverb "One picture is worth a thousand words" may well be paraphrased here as "One field excursion is worth a thousand words!"

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[18] Palmer, E. Laurence, *Over the Ground*, Cornell Rural School Leaflet, Vol. 38, No. 3, January, 1945.

Being fortunate in teaching on or near the Pacific Coast, the author for many years has made a practice of accompanying high school classes aboard a glass-bottomed boat. With shades drawn over fascinated onlookers as each gazes down into the blue-green depths, a kaleidoscopic panorama of near-shore marine flora and fauna unfolds before them. It is indeed a lesson in marine biology to be remembered after much else has slipped away.

Biology students, trained thus in vitalized science, are indeed educated in the true modern sense. An understanding of living things, together with an appreciation of their inherent beauty and relative importance in the scheme of life, and a reverence for law, for truth, and for the mutual betterment of man in a democratic society will make of these students finer, abler, and more cultured citizens.

PROBLEMS FOR GROUP DISCUSSION AND REVIEW

1. Outline the case for "systematic" presentation of secondary school biology.

2. Outline the case for "functional" high school biology teaching.
3. Why does the author seem to lean toward the "combination" method?[19]
4. Present a written outline of secondary school biology content prepared according to your own ideas.[19]
5. What topics and principles should be given stress in ninth-grade biology?
6. What topics and principles should not be stressed at this age? Why not?
7. Outline the aims and objectives of environmental biology instruction.
8. Do you agree with the "known toward unknown" philosophy? Discuss.
9. Present the case for conservation education in grades nine and ten.
10. Criticize the Arbor Day program conservation playlet. What do you like about it? What do you not like about it?
11. Prepare an outline for a similar playlet, in less detail. Choose any biological topic you consider important.
12. Discuss the importance of extended field observation at this age.
13. Discuss audio-visual education generally, from the biologist's viewpoint. Is audio-visual education limited to motion pictures, slide films, and slides?
14. Make a list of questions and stimulative problems which should be considered in connection with general environmental life science.
15. Will you personally plan to establish a "nature trail" near your high school classroom? Describe your plans.

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[19] A fourth modern method of approach, the "human" or "social" biology course, is given specific attention in the next chapter. It is designed to follow the ninth-grade studies in environmental basic life science.

Chapter 5. SOCIAL BIOLOGY

As now taught in progressive systems throughout the country, social or "human" biology is typically offered in the tenth or the eleventh grade. A certain maturity and breadth of viewpoint are required for a comprehensive grasp of social implications, hence this study is delayed until a foundational basis of general physical science and general environmental life science has been built up. Serving as it does as a preliminary to more specialized botany and zoology, as well as to chemistry or physics, however, while providing a terminal life-science course for many young people, it may not safely be placed later in the outgrowth curricular pattern.

APPROACH

When presented against a backdrop of personal and community hygiene, together with basic surveys of physical- and life-science factors, optimum conditions prevail for a thoroughly beneficial and enjoyable course for future citizens of America. Topics selected for investigation may cover a wide range of subjects, including conservation of natural resources, beneficial and harmful organisms, together with methods of propagation or control, adolescence and its peculiar social problems, continuance of the controlled sex education begun in general science, warfare,[1] environment and heredity, health education,[2] and comparative physiological and ecological problems, such as behavior of living things, especially man.

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[1] Baxter, James P., *Scientists against Time,* Little, Brown & Company, Boston, 1950.

[2] Wells, Harrington, "Science Teachers Join the Fight against Cancer," *The Science Teacher,* Vol. XVII, No. 3, October, 1950.

Social biology implies socialization within the classroom as well as in studies, and if training in social living has been adequate prior to entrance into the class, there will be little difficulty in establishing the essential rapport. Free interchange of ideas, criticisms, and suggestions will tend to flow from student to student, from committee to committee, and to and from students and instructor. Ideally there should not be a detailed course of study in this phase of development. General topics only should be decided upon, and large area units set up which meet with the mutual approval of instructor and students. When such an approach has been made, when objectives of the activity program are clear to all in terms of learning about life, the developing maturation of your students should manifest itself in their desire to take over intelligent self-direction and intercommunication concerning the experimental phase.

CORRELATION

The successful administration of a high school course in social biology, building as it does upon previous foundational studies, involves in addition a correlative plan of action and "follow-through" in terms of other subjects in the curriculum. The student of method will also do well at this point to review carefully the systematic, functional, and combination plans brought out in the previous chapter, for social biology in reality forms a fourth approach technique in itself. The socialized classroom; the community, state, national, and world outlook; the degree of integration with the social science core, all create a specialized field of biology teaching. The instructor will need to prepare himself, his students, and their parents in terms of community effort, contribution, and outlook, for cooperation and understanding are the key to successful socialized correlation.[3]

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[3] Benjamin, Harold, "The Place of the Secondary School in American Society," *School Review*, Vol. LVI, No. 11, November, 1948.

In the beginning, the social biology instructor will strive to create depth and breadth of concept in his students, together with an appreciation of the thought and behavior patterns of others. This will incorporate establishment of an international "one-worldness" of thinking as regards plants and animals, including man, together with the agricultural and geopolitical policies of human governments. To a marked degree, utilizing as it does the broader con-

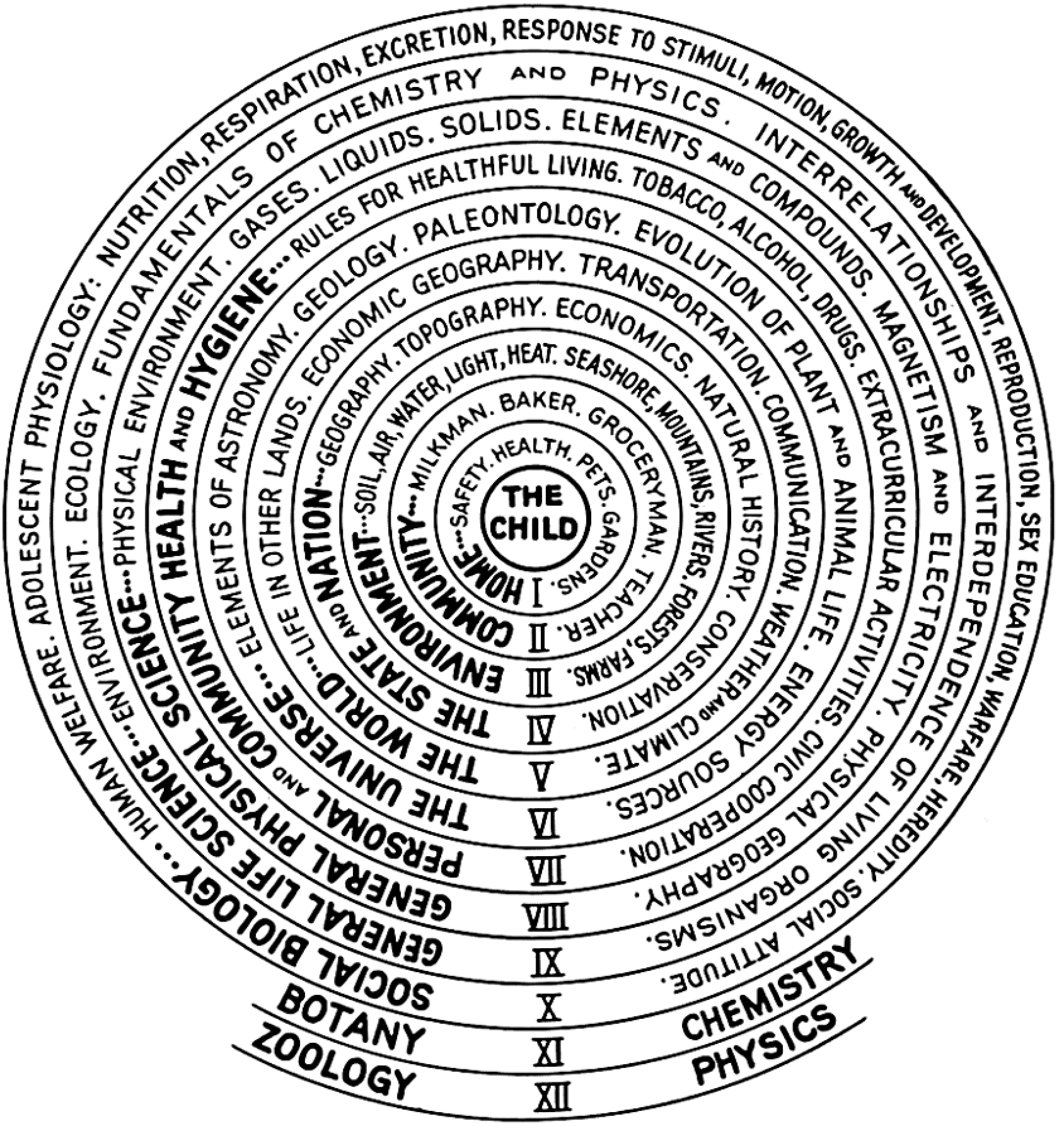
THE CHILD
HOME...SAFETY. HEALTH. PETS. GARDENS.
I
COMMUNITY...MILKMAN. BAKER. GROCERYMAN. TEACHER.
II
ENVIRONMENT...SOIL, AIR, WATER, LIGHT, HEAT. SEASHORE, MOUNTAINS, RIVERS, FORESTS, FARMS.
III
THE STATE AND NATION...GEOGRAPHY. TOPOGRAPHY. ECONOMICS. NATURAL HISTORY. CONSERVATION.
IV
THE WORLD...LIFE IN OTHER LANDS. ECONOMIC GEOGRAPHY. TRANSPORTATION. COMMUNICATION. WEATHER AND CLIMATE.
V
THE UNIVERSE...ELEMENTS OF ASTRONOMY. GEOLOGY. PALEONTOLOGY. EVOLUTION OF PLANT AND ANIMAL LIFE. ENERGY SOURCES.
VI
PERSONAL AND COMMUNITY HEALTH AND HYGIENE...RULES FOR HEALTHFUL LIVING. TOBACCO, ALCOHOL, DRUGS. EXTRACURRICULAR ACTIVITIES. CIVIC COOPERATION.
VII
GENERAL PHYSICAL SCIENCE...PHYSICAL ENVIRONMENT. GASES. LIQUIDS. SOLIDS. ELEMENTS AND COMPOUNDS. MAGNETISM AND ELECTRICITY. PHYSICAL GEOGRAPHY.
VIII
GENERAL LIFE SCIENCE...ENVIRONMENT. ECOLOGY. FUNDAMENTALS OF CHEMISTRY AND PHYSICS. INTERRELATIONSHIPS AND INTERDEPENDENCE OF LIVING ORGANISMS.
IX
SOCIAL BIOLOGY...HUMAN WELFARE. ADOLESCENT PHYSIOLOGY: NUTRITION, RESPIRATION, EXCRETION, RESPONSE TO STIMULI, MOTION, GROWTH AND DEVELOPMENT, REPRODUCTION, SEX EDUCATION, WARFARE, HEREDITY. SOCIAL ATTITUDE.
X
BOTANY
CHEMISTRY
XI
ZOOLOGY
PHYSICS
XII

FIG. 10. The *child-outgrowth formulation,* presenting science–social science integration through grade progression. (*From Wells, Harrington: Elementary Science Education, McGraw-Hill Book Company, Inc., New York, 1951.*)

cepts of the humanities, the social biology course supplements the course in secondary school economics, and the same manipulative techniques, such as panels, research teams, and symposia, are employed by alert educators.[4]

EXEMPLARY CONTENT

It may be well in these pages to indicate the probable extent to which investigation may develop content subjects within the framework of tenth- or eleventh-grade maturation. In each of the chapters of this text a portion of the material is devoted to specific examples of just what is meant in terms of actual presentation content. Social biology, being a comparatively new field, embodies much subject matter related to economic geography, for example, and to economic biology as well. Hence, a wider sampling of actual informative material will be given here than elsewhere, as a guide for younger teachers. The typical course of study outline presented with relation to each of the other chapter subjects is omitted, however, since the socializing outgrowth will depend entirely upon progressive activity. Among presentation topics covered as to content are *plant economics*, including plant utilization for shelter and food, control of weather, erosion, and pathological conditions in plants, weeds and their place in human affairs, origins of foods commonly found on American tables, applied economic geography, and important plant forms.

Animal economics (invertebrate and vertebrate) is also outlined, with special attention being given to control of injurious insects in the interest of human welfare. Injurious reptiles found in the United States may be taken up as demonstrated, together with recommended treatment for snake bite. Following a brief statement regarding the social significance of birds and mammals, a comprehensive survey of conservation of natural resources is presented, from which class topics may be drawn for elaboration in the social biology core. Properly integrated in socialized progressive classrooms, with frequent field excursions interspersed as supplementary activities, the course should definitely contribute to the maturation of all students enrolled. Pragmatically, "We learn by doing!"

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[4] Cummings, Howard, "Economic Education in the Secondary Schools," *The Journal of Educational Sociology*, Vol. 23, No. 7, March, 1950.

PLANT ECONOMICS

Panel and group discussions will bring out the fact that there is no profession, industry, or group of people which is not directly or indirectly dependent upon plants for raw materials with which to work, instruments or tools to use, clothes to wear, or food to eat. All the peoples of the world subconsciously look with respect to the plant kingdom, almost every country on earth having a botanical emblem. Egypt and India revere the lotus flower, Iran the rose, and Turkey the tulip. The chrysanthemum is the national flower of Japan. Scotland has its thistle, England its rose, and Eire its shamrock. The leek is the emblem of Wales. Spain has the pomegranate as its fruit, and the iris was the inspiration for the fleur-de-lis emblem of France. Canadian regiments march under maple-leaf banners, and so it is in all countries.

Aesthetically parks, forests, and national playgrounds draw millions of city workers from the humdrum routine of their workbenches or office desks for periods of healthful recuperation. Such changes of scene and periods of relaxation are of economic benefit to people everywhere, and tenth- or eleventh-grade students are ready for a look at life in such terms. Let there be panel discussions on this topic, in order that young people may realize how others live and work throughout the nation.[5]

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[5] See Butcher, Devereaux, *Exploring Our National Parks and Monuments,* Houghton Mifflin Company, Boston, 1949.

Shelter and Food

Plants serving to provide shelter as well as food for animals merit field study. Students living near the seashore experience the thrill of revelation when marine algae are found to house many forms of life, and any marsh or pond will reward field observation in similar manner. Birds of many types roost and nest in trees or bushes, feeding upon berries, as well as on leaves and insects. Flowers are a matter of life and death to bees, hummingbirds, butterflies, and other animal forms. Without the mulberry or in some cases the oak leaf, there would be no natural silk. Let the class extend this list to its maximum through reference work in the libraries.

Weather Control

Weather is affected to a marked extent by heavily forested regions. These form a constant source of humidity, thus influencing wide surrounding areas. Through transpiration, a single large deciduous tree, for example, evaporates several gallons of water every day. Multiplying this by millions of forest trees growing in a region will provide a conception of the role of plants in providing moisture in the atmosphere. A further instance of weather control is the planting of cypresses, poplars, rows of eucalyptus, and similar trees as "windbreaks," a practice which has important bearing upon weather conditions in many American localities. In many instances commercially profitable crops would be almost impossible without such aid.

Erosion Control

Floods are rare in wooded areas because tree and shrub roots hold moisture in the soil, runoff being gradual and erosion prevented. A primary concern of the Forest Service after a disastrous fire has denuded a great drainage area is the immediate establishment of growing "cover," which will temporarily check soil loss until new tree crops are grown. "The forest is the mother of the rivers" is a quotation often used in connection with drainage and erosion control. Floods in the vast Mississippi basin are being prevented through large-scale reforestation projects in upper tributary areas. Control of runoff further lessens the creation of "dust-bowl" regions, an additional benefit of mountain forestation. "Strip cropping" is a practice advocated by agricultural advisers in sandy locations, together with "contour farming." Each of these is an excellent topic for study.[6]

Control of Pathological Conditions

Economic harm as well as benefit is found in the plant world. Plant pathology is an important field of biological science, and research in control methods is constantly being carried on. White-pine blister rust, wheat rust, and cabbage club root are plant diseases which offer fertile fields for student investigations. Such agricultural and forest service problems provide stimuli for independent and committee investigations into the complicated life histories characterizing some of these living organisms.[7]

Investigations may lead far afield, blister rust providing an interesting illustration. This economic menace to the coniferous forested areas of the United States originated in Siberia, having been discovered in 1854. It spread with great rapidity throughout Europe, and our American white pine was extensively imported by European governments for reforestation projects. The European demand became so great for this purpose that all the forest nurseries in the United States and Canada together could not supply the required number of young trees. The nursery production of young white-pine trees became so commercially profitable that white pines were imported from Europe for further planting in this country. Since the disease is not visible until some time following infection, it was not discovered until too late; the ocean crossing had already been made! Such a pressing current economic problem with a correlative international case history is made to order for study groups in social biology.

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[6] For supplementary pamphlet material write Soil Conservation Service and U.S. Forest Service, Department of Agriculture, Washington 25, D.C.

[7] For an example of a useful reference, see Hill, Albert F., *Economic Botany*, McGraw-Hill Book Company, Inc., New York, 1937. Additional sources will be found listed under Botany in the Subject Content Bibliography, Part II, Resource Aids.

Weeds

The plant forms known as "weeds" are as applicable to study in such a class as any group. If the vigilance of gardeners or farmers relaxes even briefly, weeds insidiously resume their infiltrating tactics. Useful crops would not last long in the struggle for survival if unaided by the ingenuity and skill of man. Weeds are strong, tough, resilient, hardy, and prolific. The teacher may comment also that what we call "weeds" often are so designated because they are unwanted in a particular area. In another district the same plants might perform useful service to society. Mustards and radishes are examples. The grains are others. Many weeds are economically important because of their poisonous nature when eaten by animals.[8] "Loco weed," larkspur or "cow poison," and water hemlock are dangerous wild plants of this type. Halogeton (*Halogeton glomeratus*) kills thousands of sheep annually in our western states.

Some of the most troublesome weeds commonly found in agricultural fields and home gardens are listed below:

Bermuda or "devil" grass (*Cynodon dactylon*)
Johnson grass (*Sorghum halepense*)
Wild morning-glory (*Convolvulus servensis*)
Canadian thistle (*Cirsium arvense*)
Knapweed (*Centaurea repens*)

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[8] A practical, nontechnical reference is Kummer, Anna P., *Weed Seedlings*, The University of Chicago Press, Chicago, 1951.

Peppergrass or "hoary cress" (*Lepidium draba*)
Dodder (*Cuscuta racemosa*)
Mallow (*Sida hederacea*)
Dandelion (*Taraxacum vulgare*)
Puncture vine (*Tribulus terrestris*)
Nightshade or "white horse nettle" (*Solanum elaeagnifolium*)
Nut grass or "galingale" (*Cyperus rotundus*)
Camel's-thorn (*Alhagi camelorum*)
Filaree, "pin" grass, or "stork's-bill" (*Erodium moschatum*)
Tarweed (*Madia elegans*)
Beggar-ticks (*Bidens frondosa*)
Shepherd's-purse (*Capsella bursa-pastoris*)
Wire grass (*Polygonum aviculare*)

Integrated science sometimes leads student investigators far afield in historical research, one group having special interest in this connection: the early German "herbalists" who worked with plant uses, trying to devise new means of benefiting contemporary peoples. Carrying this early research philosophy into the present experimental and analytical age, such objectives again apply in terms of modern equipment and technology. There is practically no part of the plant structure which does not contribute today to the betterment and progress of mankind. The lowly soybean is a pertinent example, being productive of cooking fat, oleomargarine, soap, paints, linoleum, breakfast food, cheese, candy, glue, ink, wool products, and plastics. Cellulose, a basic constituent of plants, supplies another illustration, being manufactured into every sort of thing, from cellophane to automobile steering wheels.

Origins of Human Foods

Foods of plant origin are sustaining to animal life generally, and to human animal life particularly, in all parts of the world.[9] *Grains* and *seeds* are examples. True seeds of the legume type (beans and peas) are widely eaten by many

[9] The present human population of the world is estimated at 2,290,000,000.

peoples, while grains (one-seeded fruits) such as wheat, corn, rye, oats, and rice provide food for millions throughout the world. Cocoa and chocolate are obtained from seeds borne in the stem pods of *Theobroma cacao*, a native plant found in southern Mexico, Central America, and northern South America. In this connection it may be informative to your class if you make clear the distinction between *cacao* and *coca*. Leaves of the coca plant are chewed by South American natives in Peru and Bolivia; chocolate does not come from coca. The genus is *Erythroxylon*. Cocaine is derived from *Erythroxylon novogranatense*, a native of Colombia. Coffee, a bean derivative of the subtropical coffee plant (*Coffee arabica*) is a familiar American drink, the beans being imported from Brazil. Mustard (*Brassica*) is raised commercially near Great Falls, Montana, and is also commercially produced in Germany and England. Another product is vanilla, extensively cultivated in Mexico and Tahiti. Seeds of the cotton plant are pressed to extract the widely used cottonseed oil, throughout the cotton belt of our southern states. Cotton is now extensively grown in the southern section of the central valley of California, where it has been successfully introduced. Boll weevil and pink boll worm, the two major enemies of cotton growers, have so far been excluded from this area by strict plant quarantine, and use of the new mechanical cotton-picker machines is quite general. Nutmeg and its kindred spice mace are obtained from the seeds of *Myristica fragrans*, an evergreen tree found in the East Indian archipelago and also in Trinidad, on the northeastern coast of South America. Sesame and poppy seeds are used to add flavor to bread crust.

Roots used as foods include beets and sugar beets (beet sugar is the equal of cane sugar in every way), parsnips, carrots, turnips, rutabagas, and radishes, among domestic truck-garden products. Ginger, a spice grown in Jamaica, India, and Africa, is a rhizome of *Zingiber officinale*.

Stems supplying animal foods include the maple trees of Vermont and up-state New York, as well as sugar cane grown in Cuba, Hawaii, and Louisiana. Asparagus is extensively cultivated in river-delta lands. Alfalfa is an important stock feed. Cinnamon is a spice obtained from the bark of cinnamon trees, grown extensively in Ceylon. The tubers of potatoes, onions, and leeks are other edible stems.

Leaves include tea, grown in Ceylon, India, China, and Japan. Spinach, parsley, mint, and eucalyptus leaves are also important, the latter serving as the sole article of diet of the koala "bear," an endemic Australian marsupial mammal. Lettuce is an important food leaf, much of the United States being supplied from the Salinas and Imperial valleys of California and the Salt River Valley of Arizona. Technically, both celery and rhubarb are classed as leaf petioles. Mulberry-tree leaves have for many centuries been used as food for the silkworms of Japan and China.

Buds include cabbages, Brussels sprouts, and artichokes. *Flowers* are of food importance generally because of the nectar they produce, which is made into honey by bees. Cauliflower and broccoli are vegetable garden flowers. Jasmine flowers are grown in China for the purpose of making jasmine tea more fragrant. Cloves are spices derived from the flower buds of *Eugenia caryophylla,* a tree native to the Spice Islands in the East Indies.

Fruits include hundreds of types considered edible by animals, including humans. The branch of agriculture known as "pomology" is devoted to this subject. "Dry" fruits include nuts, outstanding among which is the "peanut" so extensively grown in our southern states today. High school students always like to study the growth of this legume, which has pods like peas. As the fruit matures, the pod stalks elongate, forcing the fruit down into the sandy soil, where the pods grow and develop. Finally they are dug up and stacked to dry, before being roasted as food nuts or ground to make peanut butter, the oil forming an excellent cooking fat. Georgia, Alabama, and Virginia produce most of the peanuts consumed in our country, supplemented in normal times by imports from China. Coconuts are widely native and cultivated throughout the tropics for food and for "copra." Walnuts, Brazil nuts, almonds, and chestnuts are important dried-fruit types, as are pecans.

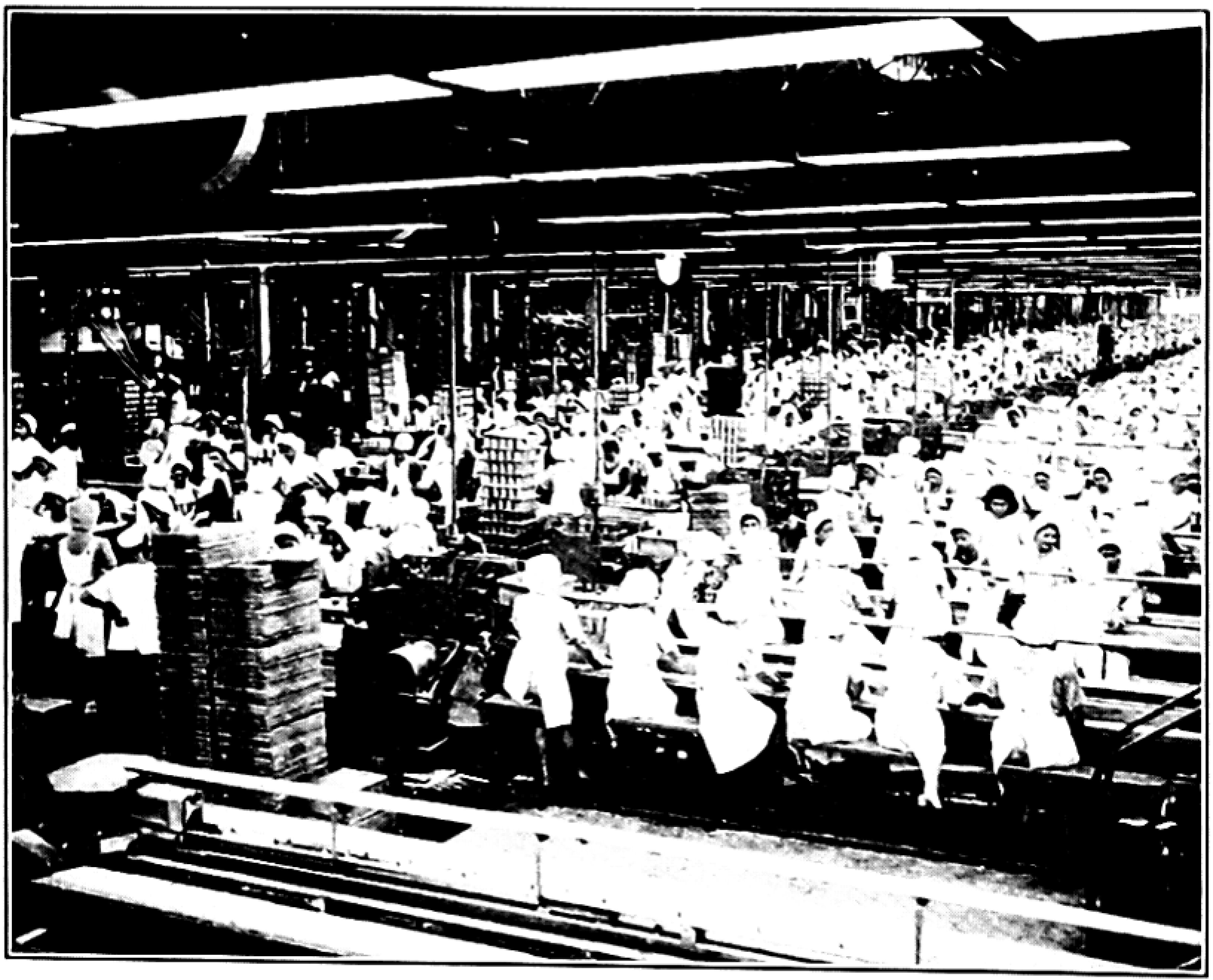

FIG. 11. Social biology includes a survey of economic crops, their production, preparation for marketing, and the peoples of the world whose economic lives are integrated and coordinated with each biological product. These women are engaged in preparing pineapples for canning, in Hawaii. This is the largest fruit cannery in the world. (*Courtesy of the Dole Pineapple Corporation.*)

Of the "fleshy" fruits, apples, dates, cherries, olives, peaches, table and wine grapes, pears, apricots, avocados, oranges, lemons, grapefruit, prunes, melons of all types, tomatoes (which are fruits, botanically speaking!), squashes, and cucumbers are important for study in the class. "Aggregate" fruits[10] (blackberries, strawberries) and "multiple"-

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[10] For definitions see Wells, Harrington, *Elementary Science Education,* section on Teacher's Reference Terminology on Fruits, in Chap. 11, McGraw-Hill Book Company, Inc., New York, 1951.

type fruits, such as figs and pineapples, are of economic interest and should be studied. Students will find that great commercial industries have arisen about the production, distribution, and marketing of each kind, the economic cooperation extended by the United Fruit Company in terms of welfare in Central American countries serving as an example.

The industry of frozen fruits and vegetables is a modern development which exerts widespread influence on the social living of United States citizens, and the "quick-freeze" process is extensively employed in the national distribution of food fish, prawns, scallops, abalones, and oysters. Persons living in Wyoming or Nevada may now readily enjoy prawns from the Gulf Coast of Florida or Louisiana, or haddock from the waters off Boston harbor. Mention should also be made of dried fruits, for many areas have developed this industry. Dates, figs, raisins, prunes, apricots, and peaches are often dried before shipping and marketing.

Applied Economic Geography

The social-science–life-science relationship is nowhere better exemplified than through the survey of economic geography of our United States. Washington leads our states in the production of apples, followed by New York, Michigan, Pennsylvania, and Virginia, usually in that order.[11] Most adults think of Georgia as the "peach" state, for example, but the truth is that California grows and markets far more than does Georgia. In fact, Georgia in 1950 ranked below California, Michigan, Washington, and South Carolina in peach production.[11] California produces approximately 100 per cent of the United States crops of olives, lemons, artichokes, almonds, and dried figs, and about 90 per cent of the wines, apricots, prunes, plums, and walnuts commercially marketed in the nation. The astonishing fact is that the first five ranking counties of the United States, in terms of value of agricultural products (Los Angeles, Fresno, Tulare, San Joaquin, and Kern) are in California!

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[11] Crop Reporting Board, Bureau of Agricultural Economics, U.S. Department of Agriculture, Washington 25, D.C.

Iowa usually leads all other states in cash farm income, followed by California, Texas, and Illinois. Florida leads the nation in production of oranges, tangerines, limes, sponges, and grapefruit. New York leads the United States in onion production, in growing of hay of all types, and in lima-bean growing. Maine, California, Idaho, Michigan, and Virginia are potato-growing areas. Most people (including teachers) consider Idaho to be our leading potato state; at least this is true throughout the West. The facts are, however, that in 1950 Maine marketed 61,750,000 bushels of potatoes, California 47,275,000 bushels, and Idaho 46,610,000 bushels. Since 90 per cent of Maine's production is in one county (Aroostook), it will be seen that this single county currently produces more potatoes than any state in the union except Maine.

Kansas leads in wheat, North Dakota in barley, and South Dakota in rye. Minnesota leads in flaxseed and clover seed, while rivaling Wisconsin in the production of butter and Iowa in eggs. Iowa usually leads all states in the production of corn, oats, popcorn, eggs, and chickens, and grows more hogs than any other two states combined! Wisconsin is usually at the top rank in terms of cheese, milk, and milk cows. North Carolina leads in tobacco-plant growing, the sociobiological importance of this industry being graphically illustrated by the increase in annual American consumption from 2 billion cigarettes in 1900 to approximately 400 billion in 1950![12] Tobacco is turned into cigarettes at the rate of almost 10 million *per hour* at the Lucky Strike factories alone.

Each section of our country illustrates progress and development along significant lines, which adds spice to economic geography and socially informed citizen-graduates to the mass of American voters. Contrary to popular opinion, Missouri is not the mule state; Mississippi is. Missouri leads in horses. Michigan is first in cherries, while New York is second only to Wisconsin in general dairy products, to Washington in apples, and to California in wine production. Maine leads in blueberries and Massachusetts is first in cranberries, while Vermont tops production of maple syrup and maple sugar. As will be seen from the outline coverage presented, the basic concepts of production, transportation, distribution, and marketing are not foreign to the social biology class; they are part and parcel of the day's work and thought. This is integrated science.

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[12] Numbers confirmed by U.S. Bureau of Internal Revenue stamps.

American *imports* should be studied with reference to world economics and geopolitics. As biological commodities vary in abundance on store shelves of the community, lead the class members to socialized discussions as to what and why, in terms of world events. Examples for study are cork, fine port wine, olive oil, and sardines from Portugal; olive oil and lemons from Italy; bananas from Central America;[13] rum and bay rum from the West Indies; wines and perfumes from France; wines from Italy, Spain, and Madeira; and pineapples from Hawaii. Mexico and Guatemala produce about 95 per cent of the world's supply of chicle, the basis of American chewing gum, a national institution. Among imported fruit products of interest to the high school class in social biology is pepper, a seasoning quite taken for granted on our school cafeteria tables. This is the fleshy fruit product of the tropical climbing vine *Piper nigrum*. Chile pepper and paprika are ground berry fruits, varieties of the subtropical genus *Capsicum*.

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[13] Symbiotic interrelationships stimulative to socialized discussion will be found in Hoyt, Elizabeth E., "Tiquisate: A Call for a Science of Human Affairs," *The Scientific Monthly*, Vol. LXXII, No. 2, February, 1951.

Important Plant Forms

Spore plants, such as mushrooms, shaggy manes, and puffballs, are often edible. The cultivation and canning of mushrooms is an extensive industry in France, Italy, and America. Many cheeses owe their flavors to the action of spore molds. Roquefort, for instance, is activated by the mold *Penicillium roqueforti,* a close relative of *Penicillium notatum,* which produces "penicillin." Bread is made with the assistance of spore plants known as yeasts, and the many brands of beer are brewed from the controlled yeast digestion of malt. Alcohol, a widely used commercial product, is obtained as a result of yeast action on corn, rye, barley, and grapes. Whisky distillation and wine fermentation are economically important industries in many countries, including the United States. Alcohol is also used as fuel, cleaning solvent, antifreeze, sterilizing agent, and as a rubdown for athletes and other active persons.

Of the many spore plants, the peat mosses (*Sphagnum*) are of interest economically, being extensively used in plant-nursery and landscaping operations. Most of the world's commercial peat moss is grown, dried, packed, and exported from Germany. The name is derived from the fact that extensive beds of this material form what is known as "peat," a cheap source of fuel much used in central European countries. Another interesting spore plant is the fly killer *Empusa muscae.* The branching threads, called "hyphae," which result from the germination of these spores send their filaments into the bodies of flies. This cancerlike growth causes the death of millions of these insect pests.

Flower seed and bulb growing is an important plant industry. We Americans have become so accustomed to the familiar little packages of ornamental flower seeds in stores that we take for granted the necessity for their commercial production. In favorable areas in various parts of the country one may see acres of growing sweet peas, larkspur, marigolds, and other flowers in bloom, being grown solely for their seed.[14] Artificial cross-pollination in selective plant breeding is practiced on a large scale in order to produce hardy strains and rare species and varieties for the market. Holland is famous for the quality of its tulip bulbs, but many bulb farms in America are proving very successful. Gladioli are grown extensively near Grant's Pass, Oregon. Daffodils do very well near Puyallup, Washington, and are grown extensively in Michigan, New York, and Oregon. Calla-lily bulbs and tuberous begonias thrive in the foggy coastal exposure of central California. Pella, Iowa, is widely known for its tulip festival. Flower breeding for expensive-perfume extraction is an allied industry, best developed commercially in France, England, and Italy.

Fiber plants include cotton, produced largely in southern and southwestern United States, Egypt, and China. Cloth, paper, thread, surgical powder, and gunpowder are numbered among the by-products, as are pyroxylin, celluloid, rayon, and cellophane. Flax is another important fiber plant, obtained from *Linum usitatissimum*, the flax plant, grown in Soviet Russia, Argentina, Germany, and Oregon, U.S.A. Linseed oil is a by-product, especially in Argentina. The flax-stem fibers are made into linen in Eire, Belgium, and other countries, as well as into canvas and lace. Jute is a bark fiber of a plant native to India, which bears the generic name *Corchorus* and is one of the most important exports of India. In many American penal institutions convicts spin the jute fibers into burlap and sacks for commercial uses. Another world-known fiber plant is the henequen cactus (*Agave sisalina*) which grows abundantly in Yucatan, Mexico. Sisal is obtained from this plant, for use in making twine.

Hemp is rope and tarpaulin material obtained from *Cannabis sativa*, a fibrous plant grown in India, China, Soviet Russia, Italy, Mexico, and the United States. Oriental hasheesh and the American "problem child," marijuana, are also economically important products of *Cannabis.* This plant will be discussed further as a flower drug plant. Another fiber, grown largely in the Philippines, is manila. The tissue from the leaf veins of *Musa textilis* are used, the product making heavy ropes, of great tensile strength. Coconut fiber is extensively used for furniture upholstery, as well as for door mats, in the United States. Surveys conducted by your students will disclose the fact that "kapok" is obtained from the inner pod linings of the silk-cotton tree (*Ceiba pentandra*), a native of Central America, Asia, and tropical Africa. It is much used commercially as a stuffing for pillows and mattresses. Lichens (tree "moss") are gathered from flat-bottomed boats in the marshes and bayous of Louisiana in large quantities for use, when dried, as mattress stuffing. Raffia, often employed in elementary and secondary arts and crafts, is a fiber-plant product obtained from the epidermis of the raffia palm leaves (*Raphia ruffia*), which grow principally on the island of Madagascar. Will your social biology students be able to locate this island?

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[14] In the Lompoc Valley of California alone, 2,500 acres of garden-flower seeds are harvested each year. The industry in this single area averages $3,000,000 annually.

Paper is an important modern product which traces its origin far back into Chinese and Egyptian history, and this topic too will form the basis of an excellent unit in the socialized biology curriculum. Books, magazines, and newspapers are printed on it. Students write letters, print signs, box gifts, and dry their hands with it. Paper is a cleansing tissue in every home, and facial tissues are used by every girl in the school. Napkins, cups, labels, streamers, wrapping sheets, Christmas bells, shelving, and hundreds of other articles are made from paper. Both rag-content (cotton and linen) and pulp papers are of plant origin, the principal sources being yellow pine, basswood, beech, fir, hemlock, spruce, and poplar trees.

The procuring and preparing of timber to form paper stock is one of America's basic social industries. The Sunday edition of one New York newspaper alone requires pulp-wood from a great many acres of timber. *The New York Times* uses more than $5,000,000 worth of newsprint each year! Multiplication of this figure by the number of newspapers and publishing firms utilizing paper, in the United States alone, will provide a staggering mathematical figure and reveal a vital problem in natural-resource conservation at the same time.

Rubber production has been an important activity in the Netherlands East Indies and in Brazil, the rubber tree (*Hevea braziliensis*) growing in abundance in these areas. American domestic supply of natural plant rubber is represented by small growth areas of "guayule" (*Parthenium argentatum*), a sagebrush type of plant imported from Mexico. During the early months of the Second World War considerable acreage was planted to this product in the Salinas Valley of central coastal California under governmental supervision and subsidy. Thomas Edison at the time of his death was engaged in important research devoted to the extraction of commercial rubber from goldenrod, but nothing of significance has been accomplished along this line since. Chicle, a latex product quite similar in characteristics to natural rubber, is obtained from the sapodilla tree (*Achras sapota*), which grows extensively on the Yucatan peninsula of southeastern Mexico.

Lumber is a primary economic product of plant stems of suitable tissue structure. Hardwoods from Central and South America, tropical Africa, and the Philippines, such as ebony and mahogany, are commercially supplemented by American lumber forests. The latter include our native soft and hard pines, spruce, southern cypress, cedar, maple, redwood, walnut, and many others. Shingles are usually made from red cedar or southern cypress, since these woods do not warp when wet. Building laths are milled from pine and spruce. "Excelsior," a plant product much used in packing operations and in furniture manufacture, is shredded from basswood, cottonwood, and poplar forests in Wisconsin and New York. Veneered (thin-sliced) woods are much used for radio and phonograph console panels at the present time. Gum trees and bird's-eye maples are of wood-grain composition peculiarly suitable for products of this type. Genuine mahogany is used in the construction of fine pleasure craft because of its extreme buoyancy. Airplane insulation and surfboards are made from balsa wood, a principal export of Ecuador. Bamboo is an important building material in China, Japan, and other parts of the Orient. Briar "burls," from bushes grown in the Mediterranean countries, are utilized in manufacture of the best grades of smoking pipes for gentlemen.

FIG. 12. The secondary school social biology class watches a cabinetmaker as he routs out grooves in hardwood cabinet panels to be used in radio receiver-set construction. Such demonstrations are invaluable in terms of life experience. (*Courtesy of the Radio Corporation of America.*)

Bark from the cork oak (*Quercus suber*) is imported from Algeria and Spain. It is processed into cork sheeting, from which commercial corks are cut. Tanning material is obtained from the bark of hemlocks, tannin being found in *Tsuga canadensis* of the eastern states and *Tsuga heterophylla* of the West and of British Columbia. The tanbark oak (*Lithocarpus densiflora*) is found from central coastal California northward to the Umpqua river in Oregon. Chestnut oak (*Quercus prinus*), the chief commercial source of tannin supply at present, is grown abundantly in New York, Maine, Kentucky, Tennessee, Alabama, and northern Georgia. The chestnut tree (*Castanea dentata*), which grows in all our central eastern states, is also utilized as a source of tannin-containing bark.

Medicinal plants are of many kinds. The marine brown algae known as "kelps" are harvested commercially by kelp barges which operate along the Atlantic and Pacific coast lines. These plants are good sources of iodine, potassium, and agar, a bacterial-culture medium. *Macrocystis, Nereocystis,* and *Laminaria* are Pacific coastal kelps thus harvested, while *Sargassum* is the most commonly used Atlantic form. It lives free-floating in an area in the Gulf Stream known as the "Sargasso Sea." Of the herbs used medicinally, peppermint (*Mentha piperita*) and spearmint (*Mentha spicata*) are grown in Indiana, New York, and Michigan. Two barks used medicinally are *Cinchona,* an evergreen native of Peru and Java, which is the source of quinine, and *Rhamnus,* the Canadian cascara. Various woods are used, notably sandalwood (*Adenanthera*) and camphor (*Cinnamomum*), grown in the East Indies, Japan, and Hawaii. Turpentine is distilled from pines (mostly *Pinus maritima* and *Pinus palustris*) which grow in Georgia, South Carolina, Alabama, and northern Florida. Soviet Russia distills and exports a large amount of turpentine.

Leaves used medicinally include tobacco, in the larger sense, for tobacco is a narcotic drug, even though mild in nature. Tobacco (*Nicotiana tabacum*) is grown in Connecticut, North Carolina, Virginia, Kentucky, Georgia, and Tennessee in large amounts domestically, while Cuba, Turkey, the Philippines, India, and Egypt furnish foreign leaves, which may be blended with American types. Other leaves used medicinally include *Eucalyptus;* the coca from Colombia (*Erythroxylon novogranatense*), from which cocaine is obtained; belladonna (*Atropa belladona*), a source of atropine; purple foxglove (*Digitalis purpurea*); bay tree (*Pimenta acris*); club-moss leaflets (*Lycopodium*); witch hazel (*Hamamelis*); indigo dye (*Indigofera*); and many others.

Flower sources of important drugs include those of *Cannabis sativa*, grown in India and Mexico, and lately introduced illegally into some parts of the United States. In the Orient the dried female flower tips are smoked as "hasheesh," "gunjah," or "bhang." In northern Mexico and southern United States the drug is known as "marijuana." In the American underworld cigarettes made from this weed are variously known as "reefers," "muggles," "grifos," or "kiffs." Smoked mixed with tobacco by college and high school students in many metropolitan centers, use of marijuana is becoming alarmingly widespread in this country. Two effects are noted among users of this powerful drug: (1) a prolongation of sensations, and (2) temporary insanity. The first effect has brought about its use to a limited extent among a few dance orchestras, since a lengthened sense of note-spacing is produced which gives musicians an illusion of time for intricate instrument manipulation. Many cases of moral delinquency and sex crime may also be traced to the smoking of marijuana among mixed groups. Suicides, murders, and daring robberies often occur while addicts are under the influence of this drug. It is a vicious, dangerous menace to the health and moral well-being of young men and women of college and high school age.

Fruits used as drug sources include opium, derived from the fruit wall of the opium poppy, *Papaver somniferum*. Morphine, an opium derivative, has medicinal uses as an alkaloid, but it is also one of the most deadly habit-forming drugs known. The dried milk, or "latex," of the fruit capsule is chewed in India and is smoked in China and in the

United States. It is less of a sociological problem in this country than marijuana, however, owing to the comparative scarcity and consequent cost of the smuggled product. Another fruit derivative, indirectly, is strychnine, a powerful drug obtained from the seeds of *Strychnos nux-vomica,* grown commercially in the Philippine Islands. Castor oil is another indirect fruit product, manufactured in the United States by pressing seeds of the castor-oil plant (*Ricinus communis*). Fruits are obtained from southern California, India, Brazil, Kansas, and Missouri in commercial quantities. These bushes are grown as garden plants in many localities. The beans are quite poisonous if eaten raw, producing severe diarrhea and abdominal pain.

ANIMAL ECONOMICS

Animal forms illustrative of economic importance will also be studied in the social biology sequence. While summarizing such animal and plant-animal interrelationships, the fact must be borne in mind that organisms are of social importance whether they are beneficial or harmful. High school students are quite generally under the impression that "importance" implies only good. If one of your students loses his purse containing a sum of money, it is not beneficial to him, but it certainly is important! One basic concept must constantly be stressed: the relationship of this study to *human welfare.*

Balance mechanisms exist in nature in more or less delicate adjustment, and disturbance of this *status quo* through "crop control" or the "not growing" of animal stock such as pigs or beef cattle may, unless carefully supervised, set in motion a disastrous set of economic circumstances. Demand, supply, injury, and reprisal are natural social and scientific factors. In your survey of economic groups along lines set up as follows in these pages, these points may well be emphasized.

Sponges

Commercial sponges of the natural type are obtained from warm waters, such as the Mediterranean Sea and the Gulf Coast of the Caribbean. Greece leads the Mediterranean countries in this industry, while Tarpon Springs, Florida, is the center for the United States, as well as for the world. The world trade amounts to about $6,000,000 annually.

Corals

Corals are of economic importance, having formed great deposits during the Devonian and Carboniferous periods of geologic time. Extensive beds of coral limestone are now found in New York and in other states. Coral islands (including atolls) in the South Seas provide habitation for plants and animals. Coral reefs, such as Bougainville, Young, Wreck, and the great barrier reefs off the northeastern coast of Australia, constitute menaces to ship navigation in tropical waters and sometimes cause economic damage. Pink and red corals of the Mediterranean and the South Seas are widely used in making necklaces and other jewelry. Some coral is priced at more than a hundred dollars an ounce, being particularly beautiful and rare.

Worms

Students in the tenth grade will have learned by now that there are other kinds of worms than earthworms. Parasitic tapeworms, liver flukes, hookworms, intestinal roundworms, leeches, and their many relatives which affect the well-being of animals are interesting topics for study, as is the lowly earthworm itself and its soil-aerating habit. Many of the members of the worm groups are of very great economic importance in terms of social biology.

Echinoderms

Starfishes are economically harmful, destroying oysters along our eastern seaboard in damaging numbers. Clams, scallops, and edible mussels are consumed by these carnivorous marine animals. State fish and game bureaus periodically conduct campaigns against these economic pests, offering bounties on starfishes in the area from Maryland to Massachusetts. Sea urchins are relished as a delicacy by the French. Sea cucumbers are highly prized as an article of diet in China, the Philippines, and throughout the Malay States. Trepang, or *bêche-de-mer*, are gathered by hundreds of fishing boats, to supply the extensive demand. If a survey of basic foods were undertaken in secondary social biology on a world basis as regards *numbers of people* who subsist mainly on each type of food, results would show sea cucumbers among the ten leaders, owing to the density of population in trepang-consuming areas. Such a survey might show results such as this: (1) fish, (2) rice, (3) corn, (4) wheat, (5) pork, (6) beef, (7) mutton, (8) trepang. Oriental use of sea cucumbers as a means of capturing edible octopuses (which the natives also relish as an article of diet) will form an interesting topic for student discussion. Sea cucumbers are tied on sticks, which are then forced under rocks at low tide. The octopuses, which do not like sea cucumbers, come rushing out, and are promptly gathered and placed in sacks.

Mollusks

All high school pupils will readily recognize the economic harm done by terrestrial garden snails and slugs, but it may be that not all students in all parts of our country will realize that many aquatic snails are economically valuable to man. Edible marine snails, such as the western abalone, are very valuable commercially. Oysters, clams, and other bivalves, such as scallops, are also valued for food. Octopus and squid are edible, being gathered for food in the Orient in large numbers.

Teredos (ship "worms") cause considerable economic damage by boring into wooden hulls of ships, as well as into the piles which support piers and wharves along our coasts. The wharves may become weakened unless watched and replaced by new timbers. Even replacement with concrete has its difficulties, for several mollusk species are rock borers, which may penetrate concrete foundations. Shell drillers cause considerable damage among edible bivalves such as oysters along the Gulf Coast and in Chesapeake Bay. Such mollusks bore into the shells, causing oysters to become watery and commercially worthless.

Mollusk shells are used as supplementary bird and chicken feed. Because of the peculiar grinding function of the gizzard, a certain amount of grit is essential for bird health. Clam and oyster shells are often returned to the water to serve as "cultch" for the catching of "spat," as swimming oyster larvae are called. Thousands of fresh-water mussel and clam shells are machine-drilled and polished in the manufacture of various types of buttons. This is an important industry in cities such as St. Louis, located near large inland waterways. Pacific coastal abalone shells, which are very beautiful, are used for a variety of novelty articles, such as lamps, brushes, combs, pocketknives, and beach-resort "souvenirs." Abalone "blister pearls," which are formed by successive encrusting nacreous layers of iridescent shell over boring invaders, are set in stickpins, tie clasps, and rings.

Genuine oyster pearls of high value are taken from the large native oysters of the South Pacific islands, when native divers bring them to the surface. Pearls are formed in somewhat the same manner as blister pearls, except that they are round, while blisters are simply raised over flat surfaces. A small, irritating grain of sand is encrusted with a layer of pearly shell, which is added to in concentric rings as the oyster gets older and larger. In the center of every real pearl is some small irritant, which caused its formation.

Pearls are artificially produced on a commercial scale by purposely introducing such bits within the cavities of abalones and oysters. Sometimes this is done in the open, over a limited area, or it may be done indoors under controlled conditions in salt-water aquaria. Genuine pearls are sold partly by weight, and there is a story to the effect that some enterprising individual once introduced BB shot into oysters, gathering large, round, heavy, lustrous pearls in a year's time! At any rate, pearls of some value are always examined under an X ray before being offered for sale by reputable dealers.

Crustaceans

Lobsters, crabs, shrimps, and crayfish are commonly used for food, the large-clawed eastern lobster (*Homarus*) being shipped by air express from Maine as far as southern California, where it vies for epicurean preference with the western clawless lobster (*Palinurus*). Small crustaceans form a considerable proportion of the diet of fishes and other freshwater or marine vertebrates, including some whales! Another socially interesting crustacean activity is the levee-weakening burrowing of *Cambarus,* the fresh-water crayfish, which occasionally contributes to broken levees at flood time in the Middle West. Barnacles must be scraped from the hulls of ships, or chemical repellent may be painted on the hulls while the boats are in dry dock, for barnacles are marine troublemakers. Large shrimps, known as "prawns," are shipped from the Gulf Coast of Florida, as well as from Morgan City, Louisiana, and the Mexican port of Guaymas, on the mainland coast of the Gulf of California.

Arachnids

In social biology, students will learn that most spiders are actually beneficial, preying upon insects, including flies. In the United States, only the black widow, or hourglass spider (*Lactrodectus*), is dangerous. *Limulus,* the horseshoe "crab" of New England, is collected for sale to universities and scientific institutions for specimen and museum use. Some species of mites and ticks transmit diseases to man as well as other vertebrates. Among such diseases are spotted fever, Texas fever, scabies, and chiggers. Scorpions of the desert Southwest are also arachnids; these are collected for general biological class use in schools.

Insects

Economic entomology is a specialized branch of social biology. Entire volumes have been written[15] concerning the harmful and the beneficial activities of insects. This group is the rival of mankind in the struggle for existence and world domination. It has been conservatively estimated that more than $2,000,000,000 worth of damage is done annually in the United States alone, without attempt to place value on the thousands of human lives which are lost each year, directly or indirectly as the result of insect attack. Moth larvae destroy woolens; caterpillars eat plant leaves; grasshoppers, beetles, and cicadas destroy field crops. Scale insects kill trees, termites destroy buildings, ants carry away food, and mealy bugs or grubs attack roots. Mosquitoes transmit yellow fever, elephantiasis, and malaria; fleas carry bubonic plague; bedbugs bite; and lice produce pediculosis.

Houseflies are of great importance in relation to human disease. These prolific insects breed in horse manure and are attracted to filth throughout their lives. Their padded feet are ideally suited to germ transmission, as may readily be demonstrated in the laboratory by allowing a fly to walk across a sterile agar culture medium in a Petri dish. Of course, all organisms thus transmitted are not harmful, but in the law of averages many of them are. Typhoid bacilli are believed to be most commonly carried by flies from exposed human excrement in unsanitary districts. *Endamoeba histolytica, E. coli,* and *Giardia lamblia* have been repeatedly found in the intestines of flies. Eggs and larvae of various parasitic worms (*Taenia, Ascaris*) may also be transmitted directly to the hands or to food eaten by humans.

Spraying or "swatting" of adult flies accomplishes some good, but much more lasting protection may be obtained through elimination of open privies, which are by no means confined to country districts. Manure piles, in which flies breed by preference, should be removed and scattered frequently, or mounted on slats above concrete maggot traps, as recommended by the Bureau of Agriculture. One fly lays an average of about five hundred eggs. These hatch in about one day, feeding as maggots in warm manure for several days, before dropping down to the ground (or into the maggot-killing concrete trap base) to pupate. Adults mature rapidly, laying eggs in about twenty-three days. The life cycle is thus complete in about one month. A period of nearly a month elapses before the females from these 500 eggs lay eggs, but the number is multiplied each time.

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[15] For example, Metcalf, C. L., and Flint, W. P., *Destructive and Useful Insects,* McGraw-Hill Book Company, Inc., New York, 1939.

Figuring on such a reproductive potential is usually done on an assumed average basis of an equal number of male and female offspring, hence there would be 250 females laying 500 eggs in the first generation. Obviously, the number of flies would mount rapidly under favorable conditions. This is, moreover, a very conservative estimate. Some entomologists claim a reproductive capacity for *Musca domestica* of more than 2,000 eggs. If all females matured and laid eggs (which does not happen in the balance of biology), all land animals would soon become the victims of flies! Of course, such figures might also be quoted for ants, grasshoppers, liver flukes, starfishes, oysters, or other superprolific organisms. Natural checks on development are extremely important to human welfare.

Control over injurious insects of all types is a pressing biological problem, one which is receiving the attention of entomologists and chemists all over the world. Methods must vary for different species and for changing environmental conditions. Among those found helpful are (1) crop rotation, which does away with current pests; (2) plowing under, which buries eggs to a prohibitive depth; (3) stubble burning, which kills eggs; (4) removal of intermediate hosts; (5) poison or contact spraying; (6) gas treatment under tents (used for citrus scale and others immune to normal treatment); (7) selective plant breeding of resistant strains; and (8) introduction of natural enemies. Entomologists are continually investigating the life history and ecological relations of insect pests, in attempts to locate control forms. Search for natural foes of olive scale and elm leaf beetles, for example, is now being conducted in the United States and Europe.

Not all insects are harmful. Many are definitely beneficial to man. Among the activities of this group may be listed the cross-pollination of flowers; the manufacture of natural raw silk, honey, and wax; and warfare against injurious forms. This is shown by *Vedalia*, the ladybird beetle, which preys upon scale insects. Many, such as the dung beetles of Egypt, may be considered as scavengers. Ants and flies are included as beneficial in some ways. Maggots of blowflies (*Calliphora*) hatch from eggs laid in decaying meat. During the First World War these fly maggots were found actually to produce healing of putrefied flesh by eating it away, while not touching healthy flesh.

The tiny wasp *Blastophaga grossorum* is an outstanding example of insect benefit to man. This wasp controls the development of Smyrna figs, considered to be the best food type. The story behind the introduction of these figs into the United States from Algeria is an interesting one. Until comparatively recent time, the delicious Smyrna varieties were held to be of a type impossible of cultivation in this country, for attempts to raise them always failed. Natives of Egypt, Algeria, and Morocco guarded their horticultural secret well, but through persistent effort the pollinating activities of this tiny insect were ascertained. A number of the wasps were imported to California on branches of wild "caprifig" trees. There they multiplied and performed their symbiotic duties, with the result that quality figs became a domestic product of this country.

The procedure is as follows: male *Blastophaga* within wild figs seek out the females as they develop, fertilizing them. The males have no wings and cannot fly, hence they do not leave their figs. The fertile females develop wings and fly away, seeking wild "caprifig" flowers only, in which they lay their eggs. They visit domestic fruit-bearing fig-tree flowers during their search, however, carrying and distributing the wild pollen as they do so. It is this wild "caprifig" pollen which is essential for domestic Smyrna-fig development, and only this genus and species of penetrating wasp can carry it.

Sharks and Fishes

Marine and fresh-water elasmobranchs and fishes are of economic importance in the secondary school survey, many being used for the benefit of man. Thousands of species are eaten as food and serve as food, in turn, for countless forms of aquatic life in the balance of nature. Sharkskin is often used for leather, and the flesh is widely sold in American fish markets. Halibut-liver oil, soup-fin-shark-liver oil, and cod-liver oil are valued for their vitamin content, although vitamin A is now synthesized. The liver oil from male soup-fins (*Galeorhinus zyopterus*) averages 85,000 units of vitamin A per gram. The "goldbeater's skin" often used in osmosis experiments is made from fish air bladders, and dog and cat food, glue, and commercial fertilizers are often fish products. A considerable amount of money is annually invested in licenses, rods, lines, hooks, lures, nets, gaffs, boats, and other angling paraphernalia by sportsmen, and many thousands of goldfish, guppies, and tropical fishes are purchased each year for home pets.[16]

Amphibians

Frogs, toads, and salamanders, as a class, are decidedly beneficial to man. Aside from their usage in college scientific laboratories as vertebrate demonstration material, which is considerable, they are of direct value in many ways.

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[16] Wells, Harrington, *Fish and Fishing,* Harr Wagner Publishing Company, San Francisco, 1946.

Organisms that feed upon them include fishes, snakes, marsh birds, weasels, skunks, and minks. Many humans consider frog legs to be very desirable as food, and it might be interesting to make a brief survey as to who among the students in the social biology class has eaten them! In gardens, as well as in the field, toads feed voraciously upon insects of all kinds. The toad is the gardener's friend.

Reptiles

Many young people have an instilled fear of reptiles in general and of snakes in particular, but this is an acquired fear; babies do not have it. Take care that your tenth-graders understand the social importance of reptiles in the world of living things. Lizards feed upon spiders. Alligator hide is highly valued for use in real alligator bags. Turtle soup is a delicacy, and small aquatic turtles are often sold as pets. The large South American iguana is a staple article of diet in tropical regions of that continent. Surprising as it may seem, a great many snakes are eaten as food in the Orient. In the Japanese city of Tokyo alone, it is estimated that a thousand snakes are eaten every day!

Student research will bring out the fact that there are but five poisonous reptiles within the borders of the United States, and even these bring a means of livelihood to some people, who collect and sell them. The Gila "monster," which inhabits the desert Southwest, is seldom seen by man and is not of general importance. There are thousands of individuals of the four poisonous snakes of America, however, and one of these might be contacted by any individual during a walk in the woods or fields, or even while swimming, in some districts. The instructor of tenth-grade social biology may well take these forms into consideration, then, in planning discussion and demonstration topics. Menace to personal well-being is a definite social threat, with the chance that injury may be the cause of sickness, loss of time from work, and in some cases, death. It is well, therefore, to know the approximate distribution of dangerous snakes and to be prepared for the treatment of snake bite if and when it does occur.

The copperhead (*Agkistrodon mokasen*) is found in Texas, Louisiana, Mississippi, Alabama, northern Florida, Georgia, North and South Carolina, Virginia, New York, and in parts of New England. It averages about three feet in length. The water moccasin (*Agkistrodon piscivorus*) is found in southern Atlantic and Mississippi Valley states. It also is a very dangerous snake. Coral, or "harlequin," snakes (*Micrurus fulvius*) are poisonous types, fairly common in northern Florida and neighboring states.

Rattlesnakes (*Crotalus*) are found in every section of the country. Their bite may or may not be fatal to humans, depending upon the physical resistance of the person struck and the size and condition of the snake, as well as the nature and speed of treatment. Many persons who have been bitten have recovered after a period of dangerous sickness. Others have died in agony, when medical aid was not available and first aid was improperly administered. Rattlesnakes rattle their tail tips as a warning, in most cases, before striking. If given an opportunity, they usually will crawl away. If teased with sticks or if surprised, they will strike from a coiled position. The poison glands are located in the upper jaw. These connect by ducts with the two large, sharp poison fangs in the upper jaw, which are hollow. As the fangs puncture the skin, muscles squeeze the poison sacs, thus forcing poison into the two punctures through the hollow fangs.

Much questionable "information" has been published, and a great deal of word-of-mouth advice has been given, concerning correct treatment for snake bites. Remedies range from copious quantities of whiskey to permanganate of potash and prepared serum. The latter, if fresh, is effective in cases involving small snakes, but less so when large amounts of poison have been introduced. Perhaps the best procedure may be outlined as follows:

1. *Sit down.* Circulation must be kept as quiet as possible.
2. *Cover the area with iodine solution,* if available. Much harm is done by secondary infection.
3. *Make a series of lengthwise cuts,* to produce free bleeding. Crosscutting may sever important arteries.
4. *Apply ligatures* or "tourniquets" between the wound and the heart. Two are better than one. These must be loosened, at fifteen-minute intervals, for a period of three or four seconds, or the tissues so cut off from blood will die and amputation will be necessary.
5. *Apply a suction pump* to the wound, if possible, or squeeze with the fingers. Mouth sucking is dangerous, as gum abrasions will absorb the poison internally.
6. *Walk* (do not run) *to a source of medical aid.*
7. *No alcohol* in any form. Alcohol stimulates the circulation, which is just what is not wanted. A later letdown would also occur when strength is most needed.

Birds

Wild birds destroy weed seeds and also garden-flower seeds, hence they may be considered both harmful and beneficial in this regard. Domestic forms are raised for eggs and meat, and the feathers of some birds are valued as millinery trimming. Pets include parrots, lovebirds, and canaries. The aesthetic value of bird companionship and song must not be overlooked. This would be a drab and quiet world without them. In all probability, it would also be decidedly unpleasant for human habitation, for birds eat insects in tremendous numbers.

Mammals

Many rodents, such as gophers, mice, rats, and jack rabbits, are harmful to man. Others, such as beavers, domestic rabbits, and chinchillas, furnish food or fur. Some carnivorous mammals are harmful, such as wolves, coyotes, tigers, wildcats, and hyenas. Others, such as dogs, domestic cats, foxes, raccoons, otters, skunks, martens, minks, and fur seals, are considered beneficial. Bears, under present conditions, are not generally troublesome. They constitute one of the major attractions in our western national parks. Whales are valuable for oil, whalebone, and occasionally ambergris, but are also destructive of ocean life. Porpoises, seals, and sea lions destroy food fishes. Elephants furnish most of the world's ivory, since walruses are becoming quite rare.

Hogs provide man with fresh pork, hams, and bacons. Cattle furnish beef and veal, as well as hides for leather. Cows give milk, which is made into butter and cheese. Sheep contribute wool, mutton, and lamb. Goats give milk, and their skins also are used. Camel hair is woven into warm, light cloth.

Transportation is furnished for man by many types of mammals under various environmental conditions. Indian elephants and water buffalo are used for labor and transportation in the jungle country of India and the Malay States. Dog teams are indispensable in the frozen North. Llamas are used in the Andes of Peruvian South America. Camels are the African "ships of the desert." Oxen serve as beasts of burden in the Orient. Horses are bred for labor, riding, and racing.

CONSERVATION OF NATURAL RESOURCES

Management and conservation of our national resources remains as an illustrative topic demonstrative of content in tenth-grade social biology.[17] Discussions with and among students may well begin with historical development, correlating with the study of early American colonization in social science classes. During the early period of land development on the American continent, conservation of natural resources was not considered at all necessary. It is doubtful that the subject was even mentioned, for in the midst of prolific abundance there seemed to be no limit to the available supply. Streams swarmed with beaver and fish. Bison

[17] Whitaker, J. Russell, and Ackerman, Edward A., *American Resources*, Harcourt, Brace and Company, Inc., New York, 1951.

roamed the plains in tremendous herds. Passenger pigeons darkened the sky, as teeming millions migrated from place to place. Great forests stretched tall and green over mountain and valley as far as the human eye could see. There was no need for conservation, for all that anyone could possibly use was available in unlimited quantities, and nature took care of plentiful replacements.

It will soon be shown through group presentations, however, that steady infiltration of population brought gradual but certain changes into the utopian picture. As decades passed into centuries, the New World took on a different aspect. Millions of people came to live in districts where trading posts formerly were located. Factories and commercial industries of all types reached out for more and more raw materials. Food, lumber, furs, textile fibers, and even water itself became commodities of barter and exchange. Pressed by ruthless competition, industrial and social units extended farther and farther into the western wilderness. Monopoly and exploitation became ends in themselves, as there was neither time nor inclination to make adequate replacement. Salmon began to disappear from the rivers. Beaver traps extended in lines into the northwestern rivers. Passenger pigeons were seen less often. Indians went on the warpath in defense of their diminishing supply of bison. Unrestricted lumbering slashed into virgin timber country, and forest fires of great magnitude destroyed much that had not yet been reached by the hand of man.

Prophets preaching the necessity for saving a part of the priceless heritage for future generations eventually began to make themselves heard. Definite steps began to be taken toward controlling encroachment, placing legal limits upon size and number of individuals taken from forest, field, and stream. Private industry itself inaugurated programs of replacement. Thus was born the conservation movement which is studied in our classrooms today.

Since the turn of the present century, American educators have realized the urgent necessity for unified action.[18] The wisdom of similar practices followed for centuries in Sweden, Norway, Denmark, Germany, England, China, and Japan is now apparent. Adolescents must continually be trained in our public schools, and the tenth-grade program in social biology provides an ideal time and place for broad emphasis upon this phase of education. Conservation education has today become an integral part of our national policy.[19]

The vital importance of planned protection, controlled expenditure, and systematic replacement of natural resources has become a basic principle of secondary school social biology. The problem must not be attacked in the vague, haphazard manner characteristic of early efforts, but dynamically by well-established state and Federal agencies, plus a vitalized program of audio-visual education backing up the classroom educational leader in the various phases of conservation, including human health and hygiene. In many institutions, entire core curricula are built about *Conservation of Natural Resources* as an integral theme. National conferences sponsored by the National Education Association, such as that at San Francisco in July of 1951, are indicative.[19]

Health education is an important facet of the conservation program which must not be overlooked in our planning of topic sequence. The author favors consideration of personal and community health, formulated upon the basis of recommended seventh-grade hygiene [20] as a culminating unit of study at the end of the year's work in social biology. At such time all contributory factors may be brought to bear in the classroom discussions, and reasons for or against certain hygienic practices (individual or community) may best be summarized at this point in the sequence of science education.

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[18] See "Education for Human Survival," entire issue of *Progressive Education,* Vol. 27, No. 1, October, 1949.

[19] American Association of School Administrators, *Conservation Education in American Schools,* Twenty-ninth Yearbook, National Education Association, Washington, D.C., 1951.

[20] Wells, Harrington, *Elementary Science Education,* Chap. 9, "Departmentalized Science in Grades Seven and Eight," McGraw-Hill Book Company, Inc., New York, 1951.

Vital health conservation issues, such as water supply and/or purification, reforestation programs aimed at prevention of floods, and the subjects of human disease prevention, detection, and medical cooperation (including socialized medicine) should be discussed at some length. Information concerning national health is readily available and will be utilized by progressive teachers.[21] Pamphlets of definite educational value on rheumatic fever, common colds, diabetes, heart disease, scarlet fever, foods, and tuberculosis, to mention but a few, may be obtained for reference with relation to the health education program.

PROBLEMS FOR GROUP DISCUSSION AND REVIEW

1. In what ways does the theory of social biology presentation differ from the systematic, functional, and combination methods?
2. What content topics are peculiarly suitable for a tenth-grade course in social biology?
3. Describe the socialized classroom procedure recommended in undertaking units.
4. In what ways and to what extent will previous science and social science studies be brought to bear?
5. What are the national botanical emblems of some countries of the world? Can you suggest possible reasons why these have been selected?
6. Discuss flood conditions in the Mississippi Valley, in terms of causes and effects.

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[21] Pamphlets on health education subjects available free and in quantity from Metropolitan Life Insurance Company. Refer to Pamphlets, Pictures, and Posters: Sources and Annotations, Part II: Resource Aids.

7. Give examples of plants causing economic harm. Show how you would introduce this subject for class discussion and project work.
8. Name some weeds which cause trouble in your locality. How will you study weeds?
9. Discuss foods of man and their production, distribution, and marketing.
10. Discuss fiber-plant and paper-pulp timber production.
11. Present some of the social biology involved in the presentation of medicinal- and drug-plant studies. What social science problems are involved, for example, in the topics "marijuana" and "heroin"?
12. Outline the economically important animal forms which you believe should be taken up for consideration in the class. Why should each be studied?
13. What relation has "supply and demand" to tenth-grade biology? Why consider this social science factor in a biology class at all?
14. Discuss the specific problem of economic insects, showing how you plan to present harmful and beneficial forms.
15. Conservation of natural resources is a basic social problem. Show in some detail how you will study this subject in and out of the formal classroom.

Chapter 6. BOTANY

There are almost as many ways of studying botany, or any biological science, for that matter, as there are laboratories existent, or capable instructors to teach in them. No one, of course, can hope to include all material directly or indirectly botanical in any year's course, therefore the wise teacher must and does include that which to him seems essential, and adaptable to local conditions. Indeed, in studying a living thing it makes little difference where one begins or stops, provided each organ and system are covered, their functions explained, and the relations of each to the whole organism understood.

Laboratory Equipment

High school botanical teaching does not require the complicated apparatus associated with collegiate instruction in plant biology. Complete laboratory equipment, while desirable in itself, is not essential to a foundation in plant lore. The simplest equipment which will effectively serve the purpose is recommended, for with the elementary study of bacteria and molds as an exception (cultures involving a degree of apparatus as well as manipulative technique), most experiments[1] may be set up quite simply. It is well that this is true, for the great majority of those enrolled in these classes are interested in learning something about plants rather than in becoming professional botanical technicians.[2]

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[1] Wells, Harrington, *Elementary Science Education*, Chap. 11, "Laboratory Experiments with Plants," McGraw-Hill Book Company, Inc., New York, 1951.

Adaptation to Environment

Particularly in secondary schoolwork, the course should deal with *living* plants as far as possible, emphasizing orientation and field ecology, hence the sequence of topics should be such as to parallel the seasonal development of regional flora.[3] To this end any arrangement of subject material must be flexible in the extreme, permitting of wide divergence from planned schedules if conditions should necessitate such procedure. To lay out an ironclad course of study and blindly follow it, regardless of local environmental conditions, is not good practice in any biological instruction, and this is especially true in the case of botany. In some sections of the South and West it matters little whether outdoor experimental demonstration is carried on in September or in January. In other parts of our country it matters considerably, for deciduous trees and shrubs are not cooperative toward attempts at outdoor leaf photosynthesis determinations during snowstorms! Indoor demonstrations with electric light on aquatic plants such as *Elodea* will be substituted, of course. The teacher of botany must maintain a flexible, interchangeable sequence, content variation being regulated in some degree by the geographical location of the urban or rural system.

COURSE OUTLINES

With these things in mind, the author presents herewith two skeleton outlines of what may be termed a typical course in general basic botany, illustrating possible variations for ecological and experimental procedures in different parts of the nation influenced by diverse climatic conditions. As will be noted, each covers the same subject matter, the difference being principally in arrangement. The course outline adapted to a mild winter climate, such as prevails in the South and West, is spaced so as to allow for the gradual development of botanical principles on a long-term basis, while that adapted to a cold winter climate, prevailing over the East and Midwest, provides for work with flowers and leaves early in the term, before the winter snows. In some years, such as the winters of 1950–1951 and 1951–1952, these arrive during early November.

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[2] Palmer, E. Laurence, "Spit 'nd Polish," *Nature,* Vol. 43, No. 6, July, 1950.

[3] Palmer, E. Laurence, *Wooded Laboratories,* Cornell Rural School Leaflet, Vol. 44, No. 4, Spring, 1951.

COURSE A: MILD WINTER CLIMATE

Unit I. "What Is Botany?"
  Biology, the study of living things.
  Botany, the biology of plants.
  The history of botany.

Unit II. "What Is the Nature of Our World?"
  Nonliving and living things.
  Chemical elements and compounds.

Unit III. "What Should We Know about Soils?"
  Problems and projects on soil forms.
    Weight, texture, relative acidity.
    Fertilizers and their use.
    Water retention and capillarity.
    Water tables and wilting coefficients.

Unit IV. "What Is Life?"
  Preliminary observation of living plants.
    Local field excursions.
  The microscope as an aid in the study of life.
    Manipulation and care.
  Protoplasm and the cell.
    Basic differences between plant and animal cells.
    Elementary composition of the living substance.
    Elementary structure and functions of plant cells.

Elementary study of plant tissues.
  Definition of a "tissue."
  Comparison between animal and plant tissues.
Life in the living animal and in the living plant.

Unit V. "What Are the Parts of a Typical Seed Plant?"

MORPHOLOGICAL PROBLEMS	PHYSIOLOGICAL PROBLEMS
Seed	Food
	Germination
Seedling	Growth and development
Root	Osmosis
	Plasmolysis
Stem	Circulation
	Transportation
Leaf	Respiration
	Photosynthesis
	Digestion
	Tropisms
Flower	Pollination
	Fertilization
Fruit	Dispersal
	Seed protection

Unit VI. "How Are Plants Related to Their Environment?"

Plant-animal interrelationships in nature.
Ecological concepts.

Unit VII. "How Are Plants Classified?"

Laboratory problems.
Field collections.
Applied studies in landscape gardening.

Unit VIII. "In What Ways Are Plants Related to Human Welfare?"

Relation of bacteria, molds, and yeast to industry and to health.
Crop rotation.
Forestry and lumbering.
Economic plant crops.
Medicinal and drug plants.
Plant pathology.

Unit IX. "How May Plant Quality Be Improved?"
The work of Gregor Mendel in genetics.
The work of Luther Burbank in plant selection.
Basic principles of plant breeding.
Field excursions to plant experiment stations, breeding areas, nurseries, and orchards. Visits to city gardens.

COURSE B: SEVERE WINTER CLIMATE

Unit I. "What Is Botany?"
Biology, the study of living things.
Botany, the biology of plants.
The history of botany.

Unit II. "What Are the Parts of a Typical Seed Plant?"

MORPHOLOGICAL PROBLEMS	PHYSIOLOGICAL PROBLEMS
Leaf	Respiration
	Photosynthesis
	Digestion
	Tropisms
Flower	Pollination
	Fertilization
Fruit	Dispersal
	Seed protection
Seed	Food
	Germination
Seedling	Growth and development
Root[4]	Osmosis
	Plasmolysis
Stem	Circulation
	Transportation

Unit III. "What Is the Nature of Our World?"
Nonliving and living things.
Chemical elements and compounds.

Unit IV. "What Should We Know about Soils?"
Problems and projects on soil forms.

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[4] Herrick, J. Arthur, "Root Hairs for Classroom Study," *Turtox News*, Vol. 29, No. 1, January, 1951.

        - Weight, texture, relative acidity.
        - Fertilizers and their use.
        - Water retention and capillarity.
        - Water tables and wilting coefficients.

Unit V. "What Is Life?"

- Preliminary observation of living plants.
- The microscope as an aid in the study of life.
    - Manipulation and care.
- Protoplasm and the cell.
    - Basic differences between plant and animal cells.
    - Elementary composition of the living substance.
    - Elementary structure and functions of plant cells.

Unit VI. "In What Ways Are Plants Related to Human Welfare?"

- Relation of bacteria, molds, and yeast to industry and to health.
- Crop rotation.
- Forestry and lumbering.
- Economic plant crops.
- Medicinal and drug plants.
- Plant pathology.

Unit VII. "How May Plant Quality Be Improved?"

- The work of Gregor Mendel in genetics.
- The work of Luther Burbank in plant selection.
- Basic principles of plant breeding.
    - Class excursions to plant experiment stations and nurseries.[5]

Unit VIII. "How Are Plants Related to Their Environment?"

- Plant-animal interrelationships in nature.[5]
- Ecological concepts.
- Observation of environmental conditions as they affect plant growth.
    - Wind, fog, rain, snow, sleet.
    - Altitude and temperature.
    - Seasonal changes in appearance of plant life.

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[5] Audio-visual aids will be employed as indicated when climatic conditions prevent actual field demonstrations. Helpful lists of slides, filmstrips, and motion pictures will be found in Part II: Resource Aids, Audio-Visual Instructional Materials.

Unit IX. "How Are Plants Classified?"
- Use of herbarium collections. Laboratory problems.
- Terminal survey of taxonomy from the viewpoint of scientific foundation.
- Comprehensive review, utilizing plant classification as a key.

TAXONOMY IN THE HIGH SCHOOL

The tremendous variety of plant life known today necessitates an orderly, systematic approach to botanical study in the higher grades.[6] To thrust such a bewildering array of scientific terminology as appears below (and in the section of Chap. 7 devoted to animal classification) before beginning students without adequate introduction and socialized discussion of need would, of course, be poor practice. It should be made abundantly clear, before any work in taxonomy is undertaken, that international adoption of the so-called "Linnaean" principles lends a practical significance to this universal method of pigeonholing the great variety of plants and animals. Students should decide for themselves that grouping with relationship and structure will provide a fundamental basis for future study and productive research, and most have matured sufficiently in science education to be ready to use such reference material with profit. A type presentation such as the following may be utilized with promise of good results:

Type Lesson

The international system of giving names to plants and animals was originally devised by a Swedish naturalist Linnaeus, presented to the world in a scientific paper entitled *Systema Naturae*, published in 1735. According to his system, the great living world was divided into two divisions, called "kingdoms." Each of these was divided into big groups called "phyla," and phyla into "classes," classes into

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[6] Butts, W. K., "Classification," *Bios*, Vol. XVII, No. 1, March, 1948.

"orders," orders into "families," families into "genera," then genera into "species," like this:

- Kingdom(s)
  - Phylum(a)
    - Class(es)
      - Order(s)
        - Family(ies)
          - Genus(era)
            - Species(ies)

It is important that we realize that *every living thing* may be classified in this manner, using subdivisions of each grouping if any are needed. A name given to a plant found growing in the Amazon jungle of Brazil, for example, has the same name and indicated relationship whether it is referred to in the scientific literature of Italy, Japan, France, or the United States. Science employs the only truly universal language, our reverence for factual truth rising above international intrigue, world unrest, war, skin color, or politics. When a worker in botanical research describes a new species or a new genus, such as the imaginary plant we have found in Brazil, he writes his description in the form of a "paper," which he sends to a scientific magazine, often called a "journal."

If the editors of the journal, each a specialist in a particular field of botany, decide that the species or the genus is really new, the paper is published, and the name given the plant then takes precedence over any other names which may later be given it by anyone anywhere. This is the *law of priority*, which prevents the confusion in science which prevails among common names. Many plants have five or ten common or popular names in various parts of our country alone, yet have but one true scientific name, the world over. Even we who are studying botany in high school can understand why this should be so.

Generic and specific names are used in discussing plants, often among people who do not speak or understand Latin any better than you or I. Soon we shall visit a commercial nursery, and you will have an opportunity to ask the plant workers there the names of some of the specimens being grown for sale. Drop into a seed and plant store, or call upon a florist, asking the names of various plants. Ask the gardener who tends the school grounds what some shrub is called. The answers you obtain will surprise you!

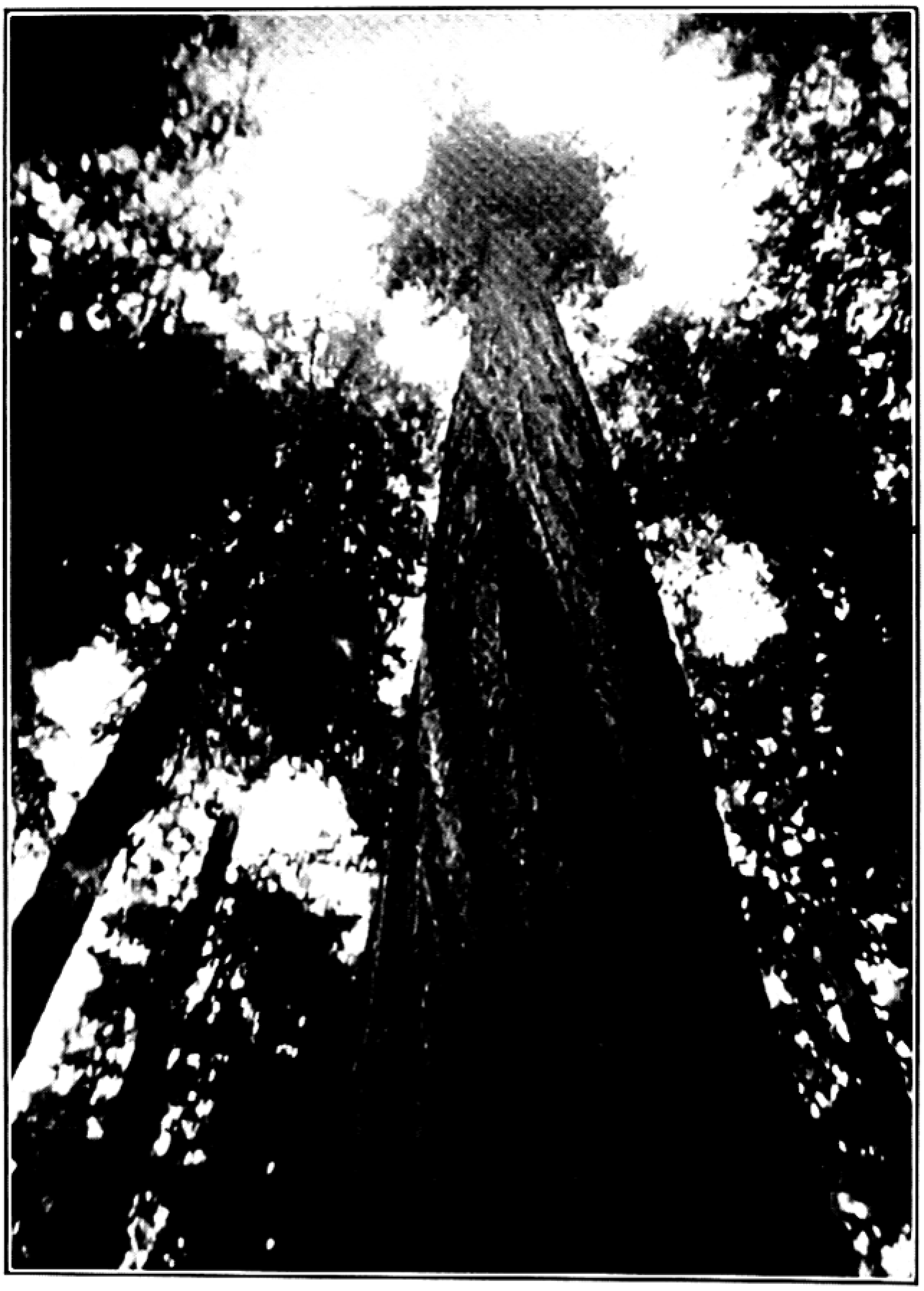

FIG. 13. Looking up at the tallest tree in the world. This *Sequoia sempervirens,* utilized to demonstrate the botanical classification in the text, towers to a height of 364 feet, higher than any other tree on earth. (*Photograph by the author.*)

It is interesting to learn the botanical names of some trees, shrubs, and flowers. As a concrete example, let us take the two species of "big trees" which grow in California, *Sequoia sempervirens* and *Sequoia gigantea*.[7] The genus (*Sequoia*) is named in honor of an Indian chief who has been credited with the invention of an alphabet for the Cherokee tribe. The specific names are descriptive: *semper-*

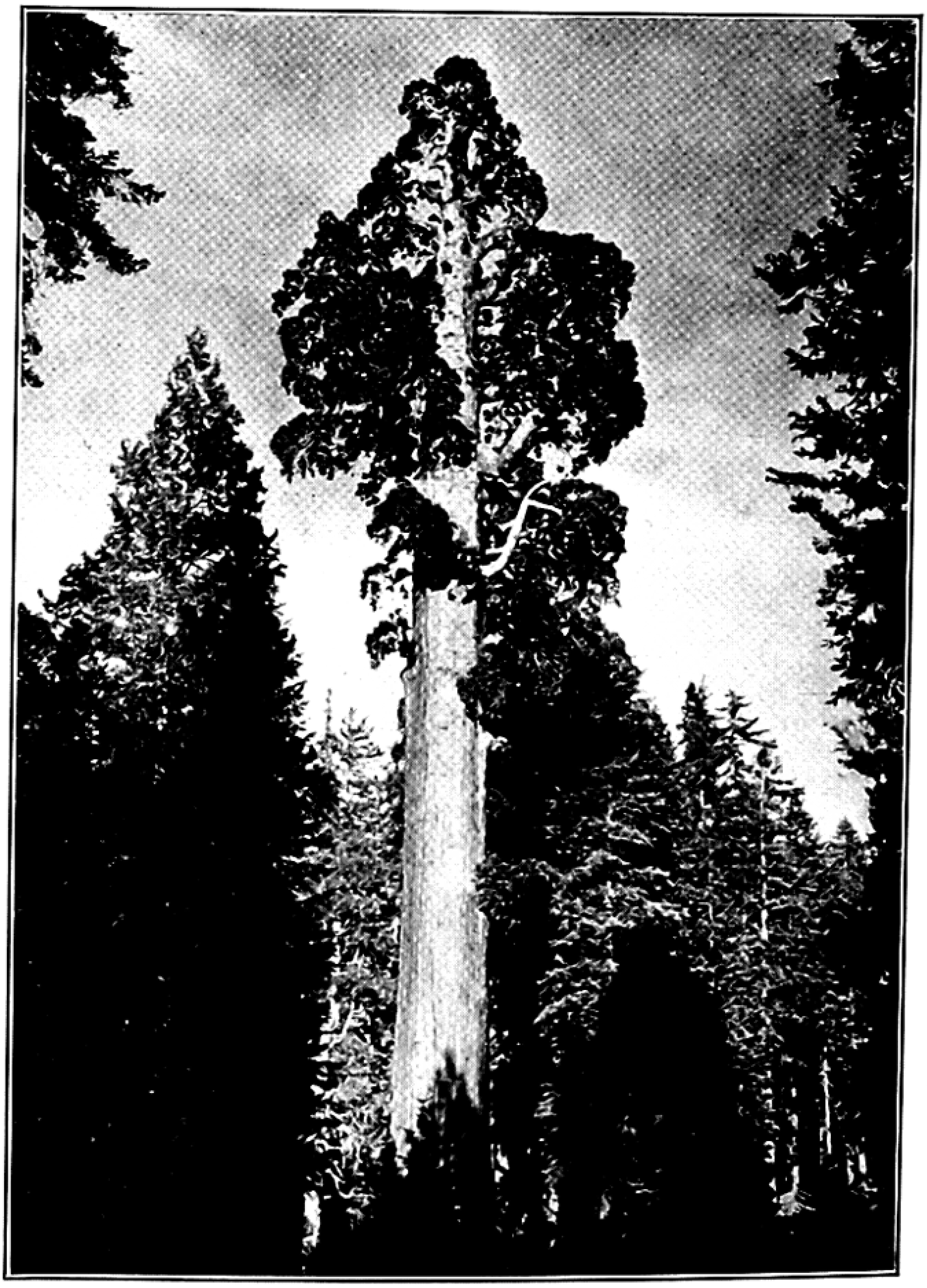

FIG. 14. The "General Grant" big tree (*Sequoia gigantea*) is one of the oldest and largest living things on earth. The trunk of this three-thousand-year-old giant is 12 feet thick 200 feet above the ground. (*Photograph by the author.*)

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[7] Photographs of two of these internationally famous trees appear on these pages and should also be represented in the laboratory of the dynamic teacher of botany as illustrations of the tallest, largest,

virens, the "redwood" of commerce, being always green and alive, showing what botanists call "stump-sprouting" around the base. A piece of the bark known as a "burl" will give off many little branching trees if the burl is placed in a shallow dish of water. The little green trees live for a long time (many months), trying to grow in this place. In nature, a redwood forest is very thick because of the growth near the bases of the mother trees, and the lumber is constantly being thinned out for commercial sale, for redwood does not decay or rot, and termites do not like to live in it. The name *gigantea* means "gigantic."

Sequoia sempervirens is the tallest living thing, one tree towering to a height of 364 feet. Using our method of classifying the principal forms of plant life we study, we would work out the "taxonomy" of this as follows:

Kingdom: *Plant*
  Phylum: *Spermatophyta*
    Class: *Gymnosperma*
      Order: *Coniferales*
        Family: *Taxodiaceae*
          Genus: *Sequoia*
            Species: *sempervirens*

Many of these terms ("Spermatophyta," "Gymnosperma," etc.) we do not yet understand, but we shall learn how they are used as we study the different kinds of plants. Already we have a good idea of the general use of "genus" and "species." Let us examine our type examples further, using now the other species, *Sequoia gigantea*. These "big trees" are often confused by persons who have lived in California all their lives, the commercial redwood being found only in the coastal range, extending up a little into southern coastal Oregon. The big trees, however, are found only in the Sierra Nevada range, inland about a hundred and fifty

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and oldest plants on earth. Botanists travel from all parts of the world to see these; your students cannot immediately do this, but they will have visual aids in functional use.

miles, and at an altitude of about 4,000 feet; these are the oldest and the largest living things on earth.

Notice, as we speak of genera and species, that the genus is always given first, just as we use our "family" names as we list our names alphabetically in school. The social "family" name corresponds to the genus; the "given" name corresponds to the species. Just like Jack Smith, sitting in the front row. Smith corresponds to the genus; Jack is the species. If Jack were a plant, and his name were *Sequoia gigantea,* he would be the biggest living thing in the world and at least several thousand years old! [8]

We note also that the generic name is always capitalized. The specific name is not usually capitalized except when it has been named after a person. Incidentally, it is considered a great honor to have a plant or an animal named after you; the animal form or the plant type will be on earth a great deal longer than you will, hence this constitutes a scientific form of honorary monument. Soon we shall begin our survey of the plant kingdom, using our new language of science as we study each kind of plant.

REFERENCE OUTLINE SUMMARY OF THE PLANT KINGDOM

The Principal Phyla and Classes, with Characteristics and Illustrative Genera [9]

Phylum Thallophyta

The "thallus" plants; oldest, most primitive, and the second largest floral group. The shortest living things (bacteria) and the longest aquatic plants (*Macrocystis*) are thallophytes. There is a uniformly low degree of differentiation and specialization, the "thallus" performing all essential physiological activities. There is no vascular tissue and no embryonic stage. There are no true roots, no true stems, no flowers, no fruits, and no seeds.

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[8] The facetious approach is that used by the author, who has found it most effective in achieving rapport in the secondary school classroom.

[9] In addition to the simplified form of the standard classification system presented, correlated with most secondary school texts in common use, the instructor may wish to acquaint his students with what may be termed an ultramodern taxonomic concept. See Jones, George Neville, "On the Number of Species of Plants," *The Scientific Monthly,* Vol. LXXII, No. 5, May, 1951.

Subphylum Algae. Fresh water, on damp logs or fences, or marine. Chlorophyll present; all plants photosynthetic.
- Class Cyanophyceae. The blue-green algae.
  - Pigments: chlorophyll and phycocyanin; occasionally phycoerythrin.
    - Type genus: *Gloeocapsa.*
- Class Chlorophyceae. The green algae.
  - Pigment: chlorophyll.
    - Type genus: *Spirogyra.*
- Class Phaeophyceae. The brown algae.
  - Pigments: chlorophyll and fucoxanthin.
    - Type genus: *Sargassum.*
- Class Rhodophyceae. The red algae.
  - Pigments: chlorophyll and phycoerythrin.
    - Type genus: *Chondrus.*

Subphylum Fungi. Found on and under ground, in fresh and salt water, in and on plant and animal bodies; practically everywhere sterile conditions do not prevail. Chlorophyll absent, hence these plants are parasitic or saprophytic. Many economically important.
- Class Schizomycetes. The bacteria. Classification of this group is still controversial. Many species look very much alike, hence staining reactions and physiological activity have been utilized in determining systematic positions. Bacteria have been demonstrated to be "pleomorphic," having more than one cultural form. In general, the following will prove adequate for secondary school discussions.
  - Coccus forms: rounded. These include the causative organisms of pneumonia, sinus infections, sore throat, pus in boils, and many others.
  - Type genus: *Streptococcus.*
  - Bacillus forms: rod shaped. True bacilli bear resistant "endospores," which render them difficult to kill. The

bacillus forms include the causative organisms of tetanus, gangrene, botulism, tularemia, and bubonic plague.

Type genus: *Bacillus.*

Spirillum forms: long; more or less curved. These cause Asiatic cholera and other dangerous diseases.

Type genus: *Spirillum.*

Mycobacterial forms: long rods, rarely filamentous. Tuberculosis, leprosy, and diphtheria are caused by these.

Type genus: *Mycobacterium.*

Iron and sulfur forms: live in sulfur and iron springs.

Type genus: *Leptothrix.*

Class Myxomycetes. The "slime fungi." These are saprophytes, reproducing by means of spores, yet moving during an animal-like "plasmodial" stage across the surface of damp logs, rocks, and grass with a type of flowing motion known to biologists as "amoeboid." [10]

Type genus: *Plasmodium.*

Class Phycomycetes. Fungus plants which resemble algae; believed by botanists to have originated from green algae in an indirect manner. Notable for the spreading "mycelium." Saprophytic or parasitic. Black mold, potato blight, and downy grape mildew are forms of economic interest.

Type genus: *Rhizopus.*

Class Basidiomycetes. The "basidial" fungi, in which spores are produced upon a specialized elevated structure known as a "basidium." Many economically important forms, including the smuts, rusts, mushrooms, and bracket fungi.

Type genus: *Puccinia.*

Class Ascomycetes. The ascus or "sac" fungi, in which spores are produced in specialized structures termed "asci." Strong "mycelia" are developed in the substratum. Saprophytic or parasitic; many economic forms. The yeasts, blue and green molds, morels and truffles, powdery mildews, and the chestnut-blight organism belong to this class.

Type genus: *Penicillium.*

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[10] See Chap. 7, Zoology, Phylum Protozoa.

Lichens. This group of thallophytes, classified by most botanists under the Order Ascolichenes, deserves special mention and climax position. In these strange plants we have ascus (or basidial) fungi combining with either blue-green or green algae to form what appears to be a symbiotic interrelationship, the alga creating food while the fungus holds on to rock or tree surface. Botanists consider, however, that the fungus is actually parasitic upon the alga, for the alga can survive without the fungus, while the reverse is not true. Economically, lichens are of further interest, since Arctic reindeer feed upon them, and the "litmus" paper used in the high school chemistry course is derived from this source. The plants are also gathered, dried, and used for stuffing cheap mattresses.

Type genera: Crustose forms: *Xanthoria.* Foliose forms: *Parmelia.* Fruticose forms: *Usnea.*

Phylum Bryophyta

Bryophytes are of two types: the "liverworts" and the "mosses." These show advancement over thallophytes in that they are definitely land plants; however, they still require moisture at certain stages. Alternation of generations is a phylum characteristic, which must be carefully explained with diagrams.

Class Hepaticae. The liverworts; low-growing, moisture-loving, shade-tolerant plants. The thallus of the sexual "gametophyte" stage is photosynthetic. Not economically important, but structurally quite interesting to students.

Type genus: *Marchantia.*

Class Musci. The mosses, some of which are xerophytic, others moisture-loving and shade-tolerant. Photosynthetic sexual plant stage. Peat moss, a special type, is best known economically, being used in nursery work with plants.

Type genus: *Sphagnum.*

Phylum Pteridophyta

The ferns, adder's tongues, horsetails, ground pines, and club "mosses." These plants show a more prominent "sporophyte" stage, and the sexual stage is less known. The fern frond, as the student knows it in gardens, is the sporophyte. Alternation of generations, as in the bryophytes. Important in landscaping and in tropical climates in preventing soil erosion. The ferns are usually taken for type study and collecting in the secondary school.

Type genus: *Polypodium.*

Phylum Spermatophyta

Those plants which reproduce by means of seeds. Terrestrial, fresh-water, and marine in habitat. First floral group in number and in importance. Gametophyte much reduced; sporophyte attains extreme prominence.

Class Gymnosperma. About 500 living species; many fossil species. Ovules not covered by ovary walls. Cones in the "conifer" group, well developed. Wind pollinated; no true flowers or fruits. Short pollen tubes. Woody perennials. "Polycot" seed structure. Pines, cypresses, firs, hemlocks.

Type genus: *Sequoia.*

Class Angiosperma. About 132,000 living species, fewer fossil species. Seeds protected by ovary walls. True flowers and fruits. Pollinated by wind, insects, birds, or water. Pollen tubes formed. Herbaceous or woody annuals, biennials, or perennials.

Subclass Monocotyledoneae (monocots). About 32,000 species. One cotyledon in the embryo. Leaves usually smooth-margined. Parallel leaf venation. Stem fibrovascular bundles scattered. Cambium dies very early in most species. "Monocots" include aquatic forms such as *Elodea* used in fresh-water aquaria in the botany laboratory, and marine plants such as eel grass and surf grass. All of the lilies are included, such as *Iris* and *Amaryllis.* Freesias, onions, and yucca plants are monocots, as are all of the grasses such as wheat, rice, rye, oats, and barley. Bamboo and corn are in this group, both being of great importance to man in various parts of the world. Vanilla, all the orchids, and the palms are monocots. The group will be studied as a whole, several genera being utilized, but the corn is usually standard in the laboratory.

Type genus: *Zea.*

Subclass Dicotyledoneae (dicots). About 130,000 living species. Two cotyledons in the embryo. Leaves usually with notched margins, showing various degrees of indentation. Netted veins in leaves. Stem fibrovascular bundles arranged in a ring; xylem and phloem tubes separated by the cambium layer, which continues to function throughout life. "Dicots" include most of the plants familiar to students. Roses, apples, peaches, plums, almonds, pears, peas, beans, alfalfa, peanuts, wistaria, acacia, barberry plants, buttercups, true water lilies, avocados, potatoes, morning-glories, mint, tomatoes, peppers, tobacco, verbenas, forget-me-nots, snapdragons, geraniums, oranges, lemons, grapefruit, poppies, mustard, fig, rubber, olives, willows, currants, sycamores, beeches, birches, oaks, daisies, sunflowers, asters, and the cacti, form a partial list. The bean is usually selected for laboratory dissection.

Type genus: *Phaseolus.*

FIELD EXCURSIONS

Ideally there can be no adequate substitute for field work in botanical study.[11] Observation of *living* plants in their natural environment is quite essential to that concept, the interrelationship of living things, which we all strive to build up in our students.[12] To this end, the botany instructor must plan (as teachers do in the elementary grades) ahead for field excursions, having well in mind just what is to be accomplished and emphasized. Probable difficulties must be anticipated, seasonal weather conditions noted, and a tentative schedule adopted in your own mind before taking the matter up with your class.

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[11] Palmer, E. Laurence, *Fieldbook of Natural History,* McGraw-Hill Book Company, Inc., New York, 1949; and Palmer, E. Laurence, "Teaching with Things at Hand Locally," *Nature,* Vol. 35, No. 9, November, 1942.

[12] Zim, Herbert S., Martin, Alec, and Nelson, Arnold L., *American Wildlife and Wildlife Plants,* McGraw-Hill Book Company, Inc., New York, 1950.

Field excursions are always welcomed by students, some anxious to observe botanical facts which will correlate their studies coincident with the theory in their texts and references, some simply happy to get outside and away for a time from school routine. You will have no difficulty with the first group, but the second (never absent from the secondary classroom) will require supervision in the field. It is well to bear in mind that only comparatively small groups can benefit from such undertakings; the larger the group, the greater the disciplinary problems involved. Proceed directly to the scene of investigation. Call upon individual students for observations; do not make them all yourself. Suggest quietly that field notes be taken by all students, which are later to be written up in the laboratory. This tends to eliminate the spirit of holiday and emphasize the studious nature of the problem.

After observations have been made, questions asked and answered by the group, and notes entered in field books satisfactorily, then it is well to allow a few moments for play or relaxation before returning to the classroom. All work and no play causes field excursions to lose their appeal, and the teacher must remember that the members of the group are adolescents. Students will appreciate this spirit of understanding and will respond the more readily when you call upon them for serious concentration. When the enjoyable moments devoted to appreciation of nature in the field are over, return promptly to the laboratory, immediately writing up the notes that were taken, or assigning this work for home study that evening.

Study Nature

That gem from Agassiz, "Study nature, not books," has been a good motto for botanical students. In the more fortunate regions, trips into the field to study associations, leaf mosaics, budding, stem growth, grafting operations, natural botanical curiosities, marine or fresh-water life, crop conditions, agricultural practices, and the like may be indulged in almost at will, the year round. Climatic conditions in other centers are not so favorable, however, and trips of this type must be planned for the fall and late spring exclusively. Geographical situations frequently determine the extent and number of field excursions, also, of course. In a rural union high school they may be of almost daily occurrence, or in a city school, for that matter, if it be advantageously located for this type of work; but in some situations the time taken to reach a desired destination prohibits many excursions, however desirable they may be.

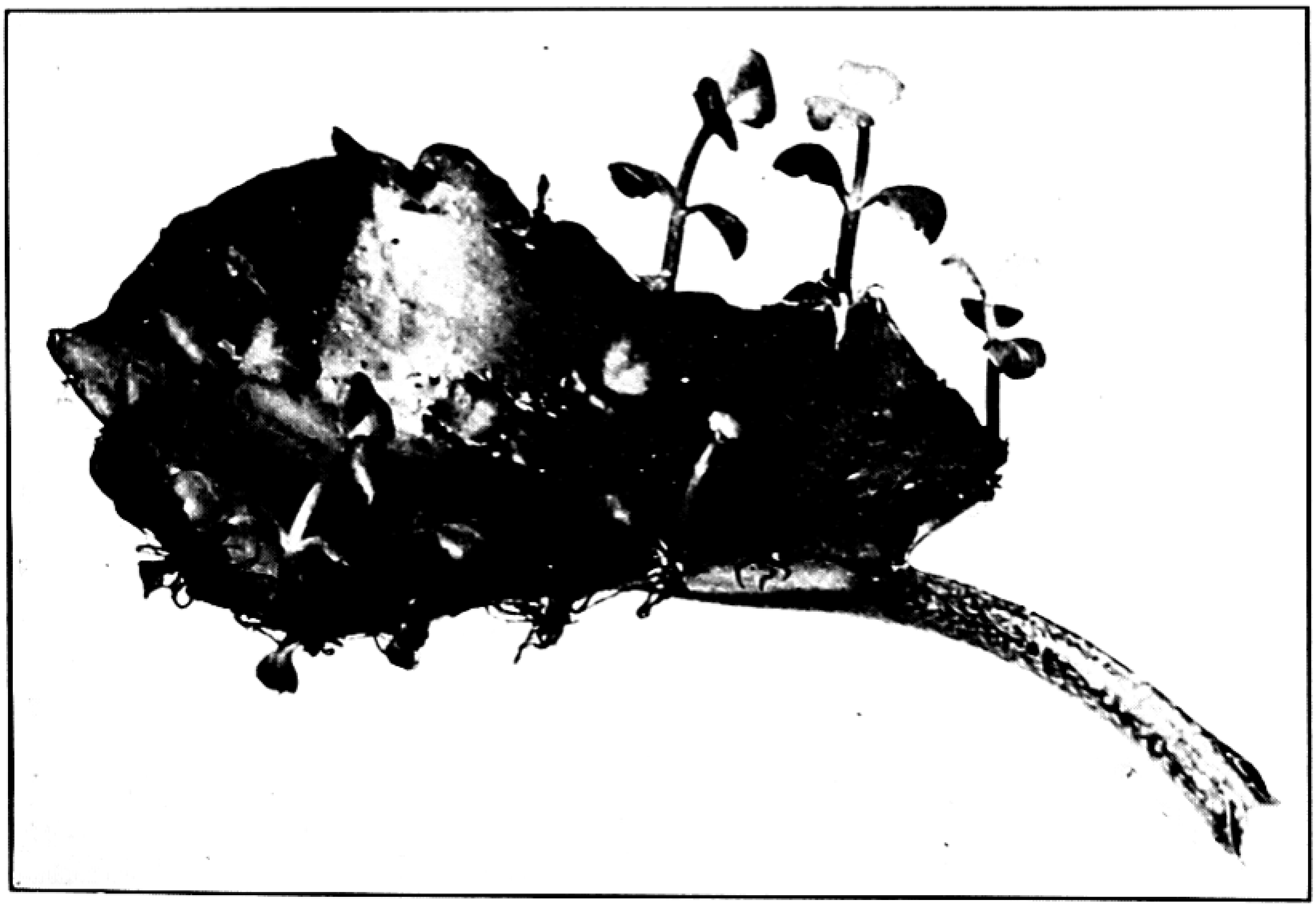

FIG. 15. Among natural botanical curiosities which may be demonstrated to the secondary school class is vegetative plant reproduction as strikingly shown in this *Bryophyllum* leaf, grown in Florida. Little plants exhibiting small root systems, stems, and leaves may be seen developing along the leaf margins. (*Photograph by Patrick H. Wells.*)

Administrative regulations are also limiting factors. Periods of time available must be closely observed and the limit not overstayed if complications are to be avoided. Saturday and Sunday trips are not usually successful, because many of the boys work on the former day, and the latter is not usually devoted to schoolwork. In the more populous districts the laboratory remains the sole instrument of use as a corollary to the textbook. The textbooks have steadily improved, since the time of Agassiz, in organization, content, and illustrative material; hence a better slogan for today is: "Study nature *and* books."

LABORATORY ARRANGEMENT

The best botany laboratory is that which combines availability of magazines and bound reference material with a physical resemblance to nature in such a way as to make it self-sufficient. A discussion of equipment and arrangement has been completed earlier. By all means establish a garden or a hothouse, if funds permit, adjacent to the workroom. The author once constructed a quite respectable miniature solarium on the window sill of a three-story high school building. The aquarium is particularly useful as well as ornamental, in that water plants studied may be grown in it and observed indoors. Potted plants of nearly all types grow well in the laboratory, climbing vines such as ivy and runners such as *Tradescantia* providing an attractive background of green.[13]

The arrangement of the laboratory will vary with instructors and with the physical plant. Southern exposure is best for plant growth, and the solarium should be so placed as to obtain the maximum amount of sunlight. Microscopic study, on the other hand, is best done under the more diffused north light. Study on dark days has until recently been a problem in this connection, but the newer laboratories are being equipped with electrical plug-in sockets for the attachment of individual and group substage illuminating microscope lamps for use in this manner. In older rooms, branch wires may be connected to a central socket and run to each table.

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[13] Shaw, Ellen Eddy, and Dorwood, Margaret, "Selection and Care of Plants in the Classroom," *Outdoors Illustrated,* Vol. 2, No. 5, November–December, 1950.

System

A place for keeping plant materials, collections, flowers in press, and means for disposal of used parts should be provided. Botanical laboratories are proverbially disorderly. Of course, the subject matter and the apparatus used render cleanliness from day to day a serious problem, but in the interest of student impression as well as that of administrators and fellow teachers who come from periods spent in comparatively neat rooms into botanical chaos, the instructor should attempt to bring about orderliness, if not scrupulous neatness, in the normal running of his laboratory. The faculty of systematic arrangement is one which should be early inculcated in your students, as this, plus the ability to think and reason out problems to logical conclusions, are objectives of science generally which are particularly applicable here. Systematic laboratory procedure will encourage similar habits in connection with written work and key manipulation in plant classification, as well as in herbarium and museum arrangement.

LABORATORY DIRECTIONS

Reasoning to a conclusion (the basing of results upon observed phenomena) is an important objective in dealing with eleventh-grade students. Of the various means used for giving directions with this end in view, the use of written manuals is perhaps best from all viewpoints. The author does not recommend the use of bound, prepared laboratory manuals for students in this connection, although much of benefit may be derived from the teacher's personal study of these publications, but rather the preparation of a manual for each special class in each individual teaching situation.

The nationally prepared manuals which accompany texts in biology, botany, and zoology admittedly have many points in their favor, among which may be mentioned a standardization of content material, ease on teacher and pupil, and intimate correlation with the text; but subject matter of local interest and import, as well as personal training and inclination of the instructor (vital prerequisites to student interest), are lacking except when the manual is used in the original teaching situation and with the text or under the state requirements for which it was devised.

Recommended Procedure

The best procedure is for the teacher to extract from several of these printed manuals, together with bound references and his own collections, a body of experiments which are *adapted to the teaching problem at hand.* Discussion of these problems with students, methods to be followed in their solution, observations to be made, excursions to be undertaken, and drawings indicated preliminary to the formulation of results and conclusions, will be necessary for each. This discussion may be oral, but some students may not hear all directions or may not get them all down on paper.

Writing the problem and method on the board at the beginning of each exercise is good but takes considerable time. Mimeographing of directions is perhaps best in all ways, as this permits adaptation to the individual situation, reserves the teacher's time and strength for conferences and teaching assistance in the botany laboratory, and puts pupils to work immediately upon entering the classroom without the time-wasting, labor-expending process of conveying directions.

The Scientific Method[14]

Whatever method is used in making clear the problem and in discussing its solution, however, the science instructor must train students to enter in their notebooks what actually happened or was actually seen, rather than what they believe should have occurred or been observed. Facts, not guesswork, must be the essence of this training. Explain early in the semester that faulty technique is inevitable, especially at first, and that if a plant experiment should not be entirely successful from a theoretical point of view, an explanation of the results obtained will prevent future errors of like nature and, at the same time, provide a sound basis for formulating accurate conclusions.

Although demonstration teaching has a marked advantage in handling the large classes found in high school science classes today, there is much to be said in favor of the laboratory method, and the instructor in secondary school botany will certainly not overlook the necessity for individual training in manipulation.[15] Whether printed, nationally published "workbooks" or the locally issued mimeographed or offset-printed class manuals are used as direction sources, observations in the laboratory and in the field may best be recorded in individual written form. Illustrative sketches may be in outline form, with little shading, and "write-ups" may now be done permanently in ink, for the science student must learn to put on paper what he sees and to mean what he says.

Summary of Objectives

The study of botany will open the eyes of many young people to the value of work accomplished by advanced students of plant science, and attention to this phase of applied botany will prove interesting to all.[16] Provision for personality development through understanding of plant life, worthy use of leisure time,[17] and aesthetic appreciation will be supplied through such phases of investigation as plant physiological processes, general classification, form and color of flowers, and economics, including problems of home, estate, and park landscaping.

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[14] Review presentation in Chap. 2, Science and the Scientific Method.

[15] Curtis, Francis D., "Individual Laboratory Work Must Be Retained," *The Science Teacher*, Vol. XVII, No. 2, April, 1950.

PROBLEMS FOR GROUP DISCUSSION AND REVIEW

1. To what extent is laboratory apparatus essential in the high school botany classroom?
2. What is meant by "seasonal sequence" in course content?
3. Discuss the botany course outlines as presented in the chapter.
4. Distinguish between morphological and physiological problems.
5. How much emphasis should be placed upon plant ecology in the secondary school?
6. To what degree and to what ends may such a detailed taxonomic outline as is presented in the chapter be used with profit by teacher and students?
7. Students will ask you why the Latin names are used in botany. How will you answer?
8. How much field work will be included in your botany classwork? Describe a typical outdoor excursion in detail, including objectives.
9. Discuss the administrative problems of the high

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[16] Zuck, Robert K., "Plant Science as a Profession," *Bios*, Vol. XX, No. 2, May, 1949.

[17] For an expression of this viewpoint in terms of botany at the college undergraduate level, see Stanfield, J. Fisher, "Range and Frequency of Courses in Botany," *Turtox News*, Vol. 29, No. 1, January, 1951.

school teacher of plant science, in terms of laboratory directions.

10. Summarize the general objectives of secondary school botanical instruction as presented in the chapter. What objectives would you include in addition to those given?

Chapter 7. ZOOLOGY

Animal biology has occupied a niche in the secondary school curriculum for many years. Early zoological pedagogy led pupils from one form to another, concentrating attention upon structure and relationship, the basic idea being to acquaint beginners with as many animals as possible in a single year's work, while strongly indoctrinating the class in terms of taxonomy. Methods of instruction as well as basic aims, however, have altered considerably during the last decade. *Applied* zoology is the cue today, with emphasis upon the civic and social aspects of the subject. Morphology, physiology, and taxonomy are employed as means to this end.

Survey

Typically, zoology is studied during the twelfth year in the high school, hence may usually be planned upon a basis of previous training in biology or botany. The long life of zoology in the secondary school is due to two causes, among others: the first a natural interest in animal life upon the part of young people, especially notable when this natural inclination has been whetted by good teaching of general biology, and the second a willingness upon the part of latter-day teachers to cater to such interest rather than to stifle it under a mass of ponderous gross anatomy and physiological detail. The popular interpretation of the science of zoology as one chiefly concerned with "the cutting up of frogs and bugs" is gradually being lived down. Applied ecology and economics, especially in the fields of aquatic biology and entomology, have been responsible in large measure for a continued interest in the study of animal life in the secondary school.

Aims

The up-to-date teacher further realizes that he is not charged with the training of professional zoologists, but rather with the conveyance to his youthful students of an *overview* of the animal kingdom and its place in the world of life and living. The best approach to such a basic aim is through a realization of the economic importance of animal forms, and it is this phase of instruction which should receive continual attention throughout the course. A plague of locusts invades the western plains; liver flukes threaten flocks of sheep in the northwest foothills; starfish menace oyster beds along the north Atlantic coast line; hookworm is again troublesome in the South; what can zoologists do about these things?

A further desirable aim may well be the development of a spirit of conservation in terms of animal resources, as opposed to wanton destruction, a tendency too often found among boys of high school age. Another objective, of course, must be basic subject coverage, proper and thorough provision being made for a comprehensive survey of the animal world commensurate with the physical and mental ages of high school juniors and seniors. Finally, well-directed students of animal biology will learn to appreciate the vast amount of previous work which has been done throughout the world both in systematic and in functional zoology, realizing the fundamental significance of scientific research in this field.

TYPE STUDY VERSUS PRINCIPLES

Examination of actual courses of study from various sections of the country reveals a wide divergence of opinion as to what constitutes a good course of study in zoology at the upper high school level. Even in cases of apparent agreement regarding objectives, there remains a chaotic lack of unity as to adequate means of attaining these ends. In some course outlines we find type study of animals to the practical exclusion of principles, while in others the reverse is true. The latter procedure seems to merit more censure than the former, considering the limited knowledge possessed by adolescents with regard to backgrounds and resource experiences.

A great deal depends upon how much biology students have had and how much they *remember*, which can only be determined upon an individualized basis through processes of pretesting and socialized discussions. Young people cannot intelligently discuss the metabolism, for example, of animals they have not yet seen. Principles have come to overshadow types in a good many places, the method having been patterned by instructors after college and university courses (and textbooks), to the detriment of sound high school presentation. On the other hand, premedical zoology, involving dissection of double-injected frogs and sharks, is equally incongruous in the senior high school laboratory. The fact that an instructor may not have been admitted to medical school and has turned to high school teaching in order to earn a living enters the picture occasionally.

Animal forms must be given dignity in terms of course of study position for themselves alone, if best results are to be obtained as foundation for principles. This does not imply overemphasis on dissection, but rather familiarity with animals under consideration with regard to general external structure, general classification (at least as to phyla), general characteristics, functioning of body parts, ecology, and economics. There must be more than the mere mention of an animal or group of animals in connection with zoological principles such as adaptive habit, serial homology, adaptation, or parthenogenesis, for example. Students cannot get far into the principles method without wondering, at least to themselves and among themselves, as to what the animals actually are like which are so glibly used as illustrations by their teacher. "What *is* this *Physalia* which illustrates polymorphism? What *is* this *Euglena* which shows both plant and animal characteristics?"

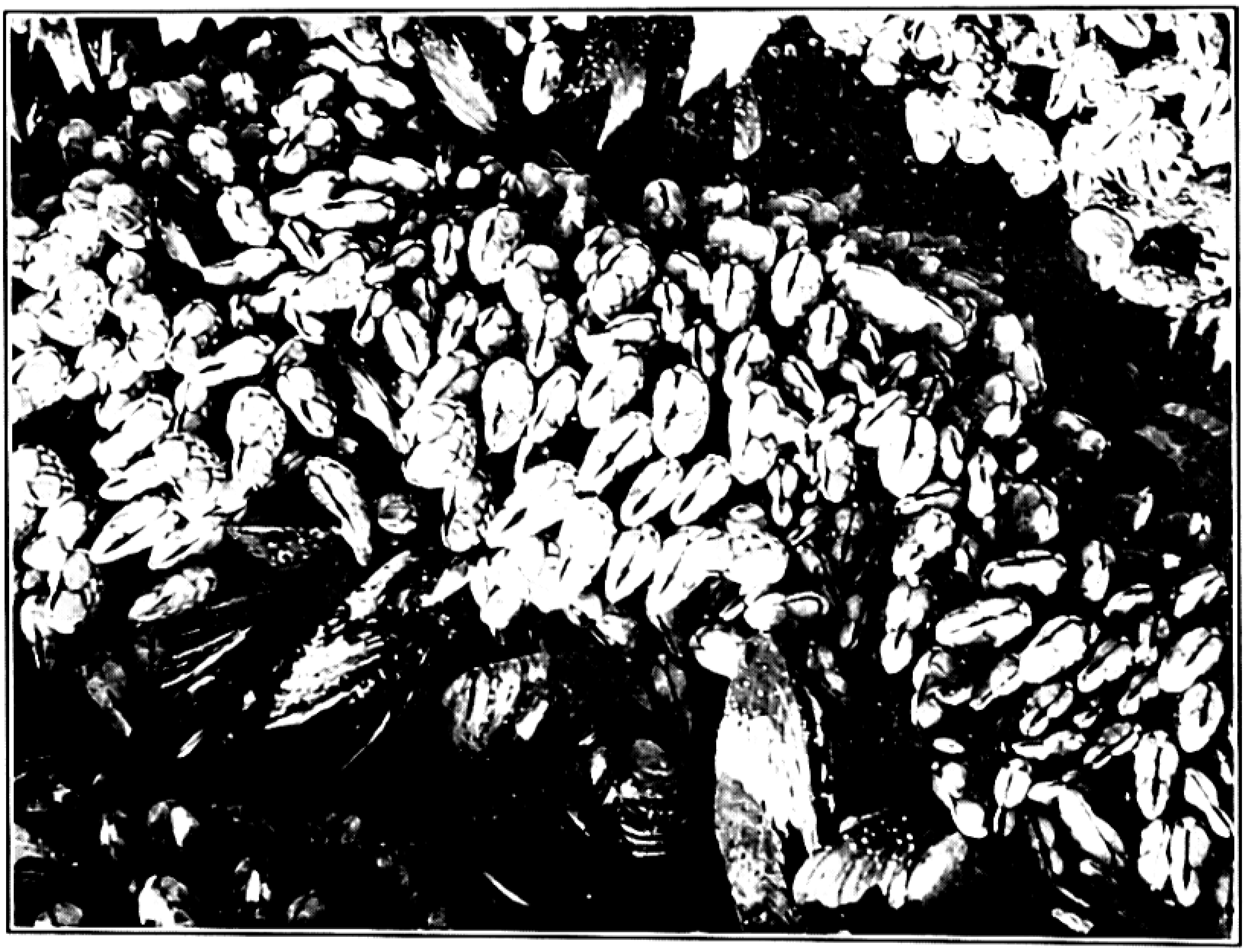

FIG. 16. Animal associations frequently offer opportunity for study of gregarious habit. The rock barnacles (*Mitella*) clustered on the rock are exposed at low tide, revealing close community life with large mussels (*Mytilus*). The closely packed grouping enables these animals to survive under the battering of the strong surf which normally breaks over the animals. This demonstrates the principle of "adaptive habit," which correlates with adaptive structure. (*Photograph by the author.*)

In working with college and university students, including those engaged in teacher-training studies, a course arranged according to the principles concept often proves quite successful, in which case we are dealing with relatively matured minds possessing backlogs of experiences and life contacts upon which they may draw for illustrative material and comparisons. Many have completed, in the senior year of high school, the very course we are here analyzing! We must never fail to take into full consideration the mental ages of people with whom we work, learning as zoologists to compromise in the high school between types and taxonomy on the one hand and principles on the other. Foundations for the latter must be carefully built up of concrete resource material, progressively leading toward generalizations and broadened concepts.

MAN AS AN ANIMAL

Boys and girls, being human, are interested in themselves and also in other things as they relate to their individual and collective happiness and well-being. This is one of the reasons why social or human biology is being so successfully taught today in so many secondary schools, as has been given previous analytical consideration.[1] The key to sustained student interest in zoology is *the relationship of animals to man.* The very organization of content material with such a primary objective in view illustrates an important concept, that of man himself as an animal form. The place of *Homo sapiens* as a living organism in the scheme of life unfolds itself logically and naturally, and a point is already won.

Teaching Plan

A well-balanced plan of action, therefore, will include a progressive study of form and relationship as bases for function, comparatively related to the human animal throughout. These topics will lead to studies in geographical isolation and distribution, animal behavior, ecological relationships, and economic importance. Enough of elementary embryology, paleozoology, evolution,[2] and genetics may be introduced to add zest while stimulating in terms of practical application, using advanced reference books which feature graphic presentation and correlate with human biology.[3] Methods of reproduction in comparative animals will form an integral part of your survey, serving to supplement the biology of sex education, while zoological principles will be continuously developed, with recapitulation at intervals as emphasis is indicated. Such a teaching plan is elastic in depth and breadth, and will culminate naturally in an upward, outward look at society in terms of man as a living animal in a world environment.

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[1] Chap. 5, Social Biology.

[2] Manwell, Reginald D., "On Teaching Perspective in Biology," *Turtox News,* Vol. 28, No. 12, December, 1950.

Course Organization

How the great body of subject material related to invertebrate and vertebrate zoology is to be organized so as best to accomplish such objectives is the teacher's own problem, and each educator worth his academic salt will wish freedom to solve it in his own way. In the author's type outline as presented below, the course in high school zoology is organized as an independent unit, presupposing little prior training in animal biology. Even when courses in general life science, social biology, or botany have been taken, reviews are definitely indicated in the high school, retention being at a minimum and subject carry-over never being very great. Difficulties related to program sequence and interschool or intercity transfer, moreover, make improbable the supposition that each student has been exposed to or has assimilated the same amount and type of previous life-science education. The following topical outline has been used by the author in teaching twelfth-grade secondary school zoology:

Course Outline for Zoology

Unit I. "What Is Zoology?"
  Biology, the study of living things.
  Botany, the study of plants and plant life.

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[3] For example, Winchester, A. M., *Genetics*, Houghton Mifflin Company, Boston, 1951.

- Zoology, the study of animals and animal life.
- The history of zoology.

Unit II. "What Is the Nature of Our Living World?"
- Nonliving and living things.
- Chemical elements and compounds in nature.
- Physical matter, energy, and life.
- Protoplasm and the cellular concept.
- Cellular biology and the human animal.

Unit III. "How Are Animals Classified?"
- Survey of animal classification as background material.
  - The Linnaean system.
  - The law of priority.
  - How and where zoological publications are submitted.
  - International aspects of the universally adopted taxonomic system.

Unit IV. "What Kinds of Animals Are There?"
- Type survey, with special attention to animal-man interrelationship.
  - Problems for study with relation to each animal form:
    - What is the animal's name? What do people call it?
    - What does it look like?
    - Where does it live?
    - How does it live?
      - What does it eat? How? Where? When?
      - How does it get air?
      - How does it move?
      - How does it get rid of waste material?
      - In what ways does it react to stimuli?
      - In what manner does it grow? Does it "moult"?
      - Are there different winter and summer colors?
      - How is it protected from its enemies?
      - What plants and animals are its "friends"? Why?
      - How does it reproduce?
      - Is it important to man? How?

Unit V. "Comparative Survey of Functions in Animal Bodies."
- In what ways are animal bodies alike? Invertebrates and vertebrates.

- In what ways are animal bodies unlike? Invertebrates and vertebrates.
- Problems and projects on comparative animal physiology.
  - Respiration (getting air).
  - Nutrition (getting food).
  - Excretion (getting rid of waste).
  - Motion (including locomotion and stationary movement).
  - Growth (comparative size, shape, and form).
  - Response to sensation (tropisms and reaction to stimuli).
  - Reproduction (budding, fission, fertilized eggs).
- Culmination studies on human physiology.

Unit VI. "In What Ways Are Animals Interdependent?"
- Problems and projects on ecological interrelationships.
  - Commensal, parasitic, and symbiotic life-habit illustrations.
    - Yucca moth (*Pronuba*) and yucca plant flower as type.
- Problems and projects on animal geography. World survey.
- Problems and projects on animal economics.
- Man as a free but interdependent living animal.

Unit VII. "In What Ways May We Improve Animal Environment?"
- Conservation of resources as related to zoology.
  - Preservation of beneficial animal forms.
  - Control of harmful animal forms.
- Concepts of euthenics and eugenics.
- Principles of heredity in animals.
  - Animal husbandry.
  - 4-H clubs and their activities. Judging criteria.
  - Human inheritance.
    - Sociology correlations. Marriage and the family.

The Problem of Classification

In the previous chapter devoted to achievement of optimum results obtainable from botanical instruction in the secondary school, considerable attention has been given to an outline survey of the plant kingdom down through classes, with general groupings indicated for orders and families. The principles of plant taxonomy were thus presented, without excessive stress upon systematic detail in the ramifications which multiply in all directions as taxonomic probing is conducted. The same problem of how far to go with classification as a usable tool of science instruction faces the teacher of high school zoology, for relationships and structural affinities must be made generally clear if genuine mastery of concept is to be ingrained.

At first glance even the limited survey presented in connection with plant and animal taxonomy would seem to be out of place in a high school methods textbook, for in actual practice little class time may be strictly devoted to drill in systematics at this grade level. On the other hand, there are sound arguments in favor of such controlled classification outlines if they are designed as broad *reference* content for use of teacher and students. This is basic material, universally sustained and acknowledged, and an attitude of appreciation for scientific thoroughness may be built up through use and recapitulation of taxonomic generalities if such content is wisely handled. Furthermore, experience has shown in many centers that high school juniors and seniors *like* systematic work in a surprising number of instances. To the several in each class who are comparatively serious in their approach, this type of solid background in botany or zoology constitutes their first real taste of scientific discipline and the scientific method.

REFERENCE OUTLINE SUMMARY OF THE ANIMAL KINGDOM

The Principal Phyla and Classes, with Characteristics and Illustrative Genera [4]

Phylum Protozoa

Unicellular animals; sometimes colonial. Many pathogenic forms.

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[4] For a more advanced taxonomic treatment, see Storer, Tracy I., *General Zoology*, Chap. 11, "Classification and Nomenclature," McGraw-Hill Book Company, Inc., New York, 1951.

Class Sarcodina. Locomotion by means of "pseudopodia," termed "amoeboid."
  Type genus: *Amoeba.*

Class Mastigophora. Locomotion by means of "flagella."
  Type genus: *Euglena.*

Class Infusoria. Locomotion by means of "cilia."
  Type genus: *Paramecium.*

Class Sporozoa. No adult organs of locomotion.
  Type genus: *Plasmodium.*

Phylum Porifera

Sponges. All species aquatic; mostly marine. Body framework of calcium carbonate, silica, or spongin. Canal systems ascon, sycon, or rhagon.

Class Calcarea. Marine, living in shallow water. Spicules of calcium carbonate.
  Type genus: *Grantia.*

Class Hexactinellida. Marine, living in deep water. Spicules of silica, the body framework resembling finely spun glass.
  Type genus: *Euplectella.*

Class Desmospongiae. Marine and fresh-water. Spicules of silica, spongin, or in combination. This class includes the natural sponges sold commercially.
  Type genus: *Euspongia.*

Phylum Coelenterata

Members characterized by the presence of a body cavity, a single opening serving as mouth and anus. All species aquatic, mostly marine. All demonstrate radial symmetry. Nematocysts in tentacles and body wall.

Class Hydrozoa. The "hydroids" (*Hydra, Obelia,* and their relatives).
  Type genus: *Hydra.*

Class Scyphozoa. The jellyfishes. Medusae have notches in umbrella.
  Type genus: *Aurelia.*

Class Anthozoa. Sea anemones, corals, sea pansies, sea pens. No medusae.
  Type genus: *Cribrina.*

Phylum Ctenophora

Numerically and economically a small and unimportant group, but one which should be touched upon for the sake of foundational completeness. All species marine, showing both radial and bilateral symmetry. Bear characteristic "combs." Have no nematocysts, but have adhesive cells on the tentacles. All are hermaphroditic (this term may be taken up here to advantage, since there is practically no sexual interest involved). Such items as the fact that ctenophores are triploblastic instead of diploblastic, however, are the province of later college zoology class instruction.

Type genus: *Cestus.*

Phylum Platyhelminthes

Flatworms. Bilaterally symmetrical. Free-living and parasitic forms. Body unsegmented. The tapeworms (cestodes) show "scolex" and "proglottids," giving appearance of segmentation; however, each of these is regarded as an individual, hence they do not demonstrate segmentation. Marine, fresh-water, terrestrial, and parasitic forms, some important economically.

Class Turbellaria. Free-living; externally ciliated.
  Type genus: *Planaria.*
Class Trematoda. The "flukes." Parasitic; adults not ciliated.
  Type genus: *Fasciola.*
Class Cestoda. Tapeworms. Soft-bodied internal parasites.
  Type genus: *Taenia.*
Class Nemertinea. Marine and free-living. Ciliated body ribbon form.
  Type genus: *Lineus.*

Phylum Nemathelminthes.

Cylindrical or roundworms. High school students should be informed that these are not "round" like a tennis ball, but more tubular like a piece of macaroni, hence "round" in the cylindrical sense. Body unsegmented. Species free-living or parasitic. No body cilia or paired appendages. Bilaterally symmetrical.

Class Nematoda. Intestine present; no proboscis.
  Type genus: *Necator.*

Class Acanthocephala. No intestine; with proboscis.
Type genus: *Echinorhynchus.*

Phylum Annelida

Segmented worms, cylindrical or flattened. Fresh-water, marine, or terrestrial forms. Such principles as metameric segmentation best demonstrated here. The earthworm is the principal form of economic and biological interest.

Class Chaetopoda. Marine, fresh-water, and terrestrial species. Some show parapodia, some cirri, some setae.
Type genus: *Lumbricus.*

Class Archianellida. All marine. No setae or parapodia. Tentacles. External segmentation indistinct.
Type genus: *Polygordius.*

Class Hirudinea. Usually fresh-water. No setae; no parapodia. Without tentacles; with suckers. Historically interesting medicinal leech.
Type genus: *Hirudo.*

Class Gephyrea. All marine, not segmented in adult stage. Proboscis.
Type genus: *Sipunculus.*

Phylum Echinodermata

All marine. Radial symmetry. Water vascular system. Exoskeleton. Unique pentamerous body plan. This group is undoubtedly one of the most motivating in zoology and should be studied, whether the school is near the ocean or not. Strange body forms and ecological habits. Two economically important groups.

Class Asteroidea. Starfishes. Hard, tough exoskeleton. Harmfully carnivorous.
Type genus: *Asterias.*

Class Ophiuroidea. Brittle or "serpent" stars. Wriggling rays.
Type genus: *Astrophyton.*

Class Echinoidea. Sea urchins and sand dollars. Long or short spines. Herbivorous. Some species edible.
Type genus: *Strongylocentrotus.*

Class Holothuroidea. Sea cucumbers. Skeletal spicules imbedded in the skin. Anal respiration, utilizing unique "respiratory trees." Eviscerating response. Economic "trepang," or *bêche-de-mer*, used for food.

Type genus: *Cucumaria.*

Class Crinoidea. Deep-sea lilies. Reference study only.

Type genus: *Pentacrinus.*

Phylum Mollusca

Fresh-water, marine, or terrestrial. Unsegmented. One ventral muscular foot. Shell usually present (univalve or bivalve). Bilaterally symmetrical.

Class Amphineura. Chitons. Flattened dorsoventrally, with a prominent foot. Eight overlapping dorsal skeletal plates.

Type genus: *Ischnochiton.*

Class Gastropoda. Snails and slugs. Land, fresh-water, or marine. The shell, when present, is usually coiled. Univalves.

Type genus: *Helix.*

Class Pelecypoda. All aquatic, mostly marine. Bivalves.

Type genus: *Ostrea.*

Class Cephalopoda. Octopi and squids. Marine. Prominent tentacles, bearing suckers. Structural location of mouth, suction of tentacle suckers, and morphological feature of the tentacles as part of the "single ventral muscular foot" will need careful explanation.

Type genus: *Polypus.*

Class Scaphopoda. Tooth shells. All marine; sand-boring; rare.

Type genus: *Dentalium.*

Phylum Arthropoda

Jointed appendages. Exoskeleton. Body divided into head, thorax, and abdomen. Dorsal heart. Ventral, solid nervous system. Numerically the largest phylum, since the insects are included.

Class Crustacea. Lobsters, crabs, shrimps, crayfish, barnacles, sow bugs, and other small relatives, such as "branchiopods," "ostracods," and "copepods," many of which are important in the balance of life. Geologically interesting "trilobites" are extinct crustaceans. Characterized by two pairs of antennae, gill aquatic respiration, and by having the head and thorax united to form a "cephalothorax." The body in each case is protected by a thin but strong exoskeleton, crusty and limy in the larger forms.

Type genera: *Homarus, Cancer.*

Class Insecta. The insects, characterized by one pair of antennae, breathing by air tubes, usually in the abdomen. Separate head, thorax, and abdomen. Three pairs of walking legs. Numerically the largest and economically one of the most important animal groups. Grasshoppers, ants, dragonflies, bees, wasps, termites, moths, butterflies, beetles, flies, fleas, bedbugs and many other forms. "Incomplete" and "complete" metamorphosis will need emphasis. Of the many insects which will be studied, anatomical detail is usually pointed out in the large grasshopper.

Type genus: *Romalea.*

Class Arachnida. Spiders, scorpions, mites, ticks, and the horseshoe or king "crab," *Limulus.* The group is characterized by absence of antennae, by four pairs of walking legs, and by having the head and thorax fused to form a "cephalothorax."

Type genus: *Latrodectus.*

Class Myriapoda. Centipedes and millipedes. Many pairs of walking legs. Air-breathing; one pair of antennae. Many body segments.

Type genus: *Scolopendra.*

Class Onychophora. A rare arthropod group, seldom studied in the high school laboratory, but included for taxonomic completeness with regard to classes. Of evolutionary interest, having structural similarities in common with annelid worms.

Type genus: *Peripatus.*

Phylum Chordata

Phylum characteristics include a notochord, paired gills or gill slits, a dorsal nerve cord, and bilateral symmetry. Three subphyla of lesser importance for high school study should be recognized in passing, the Enteropneusta, Tunicata, and Cephalochorda. Emphasis should be upon the Vertebrata.

Subphylum Enteropneusta. Rare wormlike chordates; burrow in sand.

Type genus: *Dolichoglossus.*

Subphylum Tunicata. Simple and compound ascidians; sedentary forms.

Type genera: *Styela* and *Amaroucium.*

Subphylum Cephalochorda. Marine chordates of the Amphioxus type.

Type genus: *Branchiostoma.*

Subphylum Vertebrata. The unfamiliar and familiar "vertebrates." Vertebrate chordates all show overlapping vertebrae (from which the group takes its name), an internal skeleton of bone, cartilage, or both, a dorsal nervous system, and red blood. The heart is located ventrally. Eyes, ears, and nostrils are usually on the head. Eyelids and separate teeth (fishes do not show eyelids, and turtles as well as birds do not show separate teeth). There are never more than two pairs of limbs.

Class Cyclostomata. Adaptable blooded. Without jaws and without lateral fins. The hagfishes and the lampreys.

Type genus: *Petromyzon.*

Class Elasmobranchii. The sharks and rays. Cartilaginous endoskeleton. No air bladder. No lateral lines. Pointed (placoid) scales.

Type genus: *Squalus.*

Class Pisces. Fishes, including the lungfishes (dipnoi) and the bony fishes (teleosts). Body endoskeleton, air bladder (or lung), lateral lines, flat scales. Heart of one auricle and one ventricle.

Type genus: *Salmo.*

Class Amphibia. Frogs, toads, salamanders, newts. Young are aquatic and fishlike, with lateral lines, tail fin, heart of one auricle and ventricle, gill breathing. Adults terrestrial (in the frog and toad markedly so). Heart of two auricles and one ventricle, legs, breathe air with lungs. Characteristic metamorphosis studied in the frog.

Type genus: *Rana.*

Class Reptilia. Turtles, lizards, snakes, alligators, crocodiles, chameleons, iguanas, horned "toads." Adaptable-blooded, air-breathing, scales or bony plates present, no metamorphosis, heart of two auricles and one ventricle, except in the alligator group.

Type genus: *Crotalus.*

Class Aves. Birds; characterized by the presence of feathers. Air-breathing, body supported on two limbs, heart of two auricles and two ventricles, completely separating pure and impure blood. Many orders, several including groups of economic interest.

Type genus: *Gallus.*

Class Mammalia. Mammals; characterized by warm (constant-temperatured) blood, hair, and nourishment of the young by means of mammary glands. All, except the "duck-billed platypus" and the spiny anteater, give birth to living young. Many economically important orders.

Type genus: *Homo.*

Collection and Preparation of Classroom Materials

The collection and preparation of specimens merits special consideration in connection with secondary school zoology, for much of the teaching material used in the classroom is often so obtained by teacher and pupils. In general, of course, the best pedagogical as well as psychological results are to be derived from field and laboratory observation of living animal forms rather than through dissection and detailed study of preserved specimens. The latter, however, have their place in every well-balanced course, filling breaches in opportunities for field ecological observing when such studies are curtailed by adverse weather conditions or other limiting factors.

Laboratory studies are in themselves advantageous; indeed, they actually add spice to field studies when properly controlled and interspersed. Such practice further makes use of zoological organisms from far-off places—for example, the study of echinoderms in Hutchinson, Kansas, or of sea horses in Boise, Idaho. Week-end and summer-vacation periods may be profitably occupied with exciting collecting expeditions, for every zoologist enjoys such outdoor activities. Personal specimens thus obtained, combined with the hundreds of selections available from the commercial supply houses, will provide the high school laboratory with a functional and fascinating panorama of animal life.[5]

Nature Clubs

School life-science organizations, such as the nature club, will have a part in collecting specimens and in arranging them in suitable form for group study, and student participation with group leaders in such field expeditions will not only be currently interesting but of long-term benefit as well. Such organizations as the Audubon Junior Club[6] fill a need for socializing group activities, as they stimulate student interest in natural history, both desirable in terms of educational psychology and sociology, as well as from the viewpoint of enlightened science education.

Keeping Animals Alive

As noted above, zoological specimens are of greatest interest when alive; hence, whenever possible, actual animals should be brought into the classroom for observation. "Dead" zoology is unavoidable under geographical and climatic circumstances, and preserved specimens have a definite place. Live zoology, however—including birds, rodents, reptiles, small mammals, aquatic crustaceans, ant colonies, working termites under dark cover, bee colonies in window-box hives, trap-door spiders burrowing behind glass partitions, marine ghost shrimps' (*Callianassa*) gregarious burrowing activities, and colorful, active fish in semibalanced aquaria—has unending fascination for young people.

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[5] See Part II: Resource Aids, Commercial Sources of Equipment and Supplies.

[6] For directions of assistance in forming an Audubon Club for young people, write to the National Audubon Society, 1000 Fifth Ave., New York 28.

Fresh-water and marine forms may often be carried long distances to the school laboratory for inclusion in aquarium-stocking projects, if covered with damp grass or seaweeds. If small specimens are to be thus transported, they may be carried directly in water, if the jars are not crowded, and if natural enemies are not bottled up together! Marine animals are especially susceptible to crowding and will never last long when oxygen supply is inadequate. Crustaceans, such as small rock or hermit crabs, are perhaps the most hardy, since many of these creatures are accustomed to staying out of water.

Use plenty of water (fresh or salt) and shake the containers frequently during transit, for the net result is worth the time and effort only if your animals arrive at their destination in good condition. Nothing dispels enthusiasm for zoology quite so effectively as the viewing of dead, dying, or odorous remains of what might formerly have been beautiful animals. A point to keep in mind is the fact that large living forms do not keep well in laboratory containers after arrival, hence smaller specimens should always be selected where there is a choice. A large extra container, such as a milk can, filled with some of the original water from which the animals have been taken, will be found valuable in acclimating field specimens to their new laboratory environment.

Anaesthesia and Preservation

When preservation of contractile animals in expanded condition is desired, or in the taking of terrestrial types such as arachnids or insects, anaesthesia is often employed in practice. It is a fact long known to field collectors that many aquatic specimens tend to disintegrate, to invaginate, or to eviscerate when killed too quickly by placing directly in preservative. The "twenty-ray" starfish (*Pycnopodia*) is an example, the many rays of this large echinoderm detaching themselves through autotomy, even while the fresh living specimen is being handled out of water en route to its container! Such an animal must be "put to sleep" in some manner, even for successful drying. It should be placed upon a flat surface, slowly treated with fresh water, then subjected to the action of chloretone crystals in solution. When this treatment is carried out over a period of time, the animal becomes so anaesthetized that it may be preserved intact with standard preserving *formalin,* prepared by adding ten parts of water to one part of commercial formaldehyde.

Sensitive aquatic invertebrates, such as *Cribrina, Metridium, Hydra, Obelia, Aglaophenia* or *Renilla,* may not be preserved with tentacles expanded by simply placing field specimens in formalin solution, for the instant such forms come into contact with the acid stimulus, they forcibly contract, often forming shapeless masses and concealing all normal form and color. Nudibranch mollusks of all types, including the marine sea rabbit *Tethys,* so beautifully formed and colored in the field under salt water, are other examples of contractile forms. Both alcohol and formalin solutions fade the coloring of these interesting gastropods, so the colors may not readily be preserved by nonprofessional personnel. Body formation, however, may be preserved in specimens through the prior use of anaesthesia.

In addition to chloretone, which is not always available or obtainable, ordinary Epsom salt crystals work satisfactorily with many aquatic animals. After placing the live specimens in clear water for a brief period, add a few crystals each morning and afternoon for a few days. The animals, thus subjected to gradual drowsiness, will slowly become immobile. Test with a glass rod occasionally, to determine the degree of anaesthesia. When no contractile response is obtained, place the specimen in killing alcohol or formalin.

Insect Collecting and Mounting

This is a comparatively specialized field activity. Specimens should be collected with forceps or insect nets, being placed in widemouthed, thick-walled, compact "killing jars."

Cyanide, ether, or carbon tetrachloride (cleaning fluid) may be used as the killing agent in the bottom of the collecting jars, or in little wick-containing bottles inverted in the corks, as commercially available. Carbon tetrachloride is generally preferable for school use. In homemade jars, the reagent may be poured upon cotton and placed in the bottom of the jar, then covered with a small piece of tin plate or perforated cardboard, in such manner that the gas and not the liquid comes in contact with the insect. Carbon bisulfide is also used occasionally, but this reagent has a strong and unpleasant odor.

After the collecting trip, the killed insects or arachnids should be removed and placed upon drying boards for drying and hardening in desired positions, attention being given to walking leg arrangement and wingspread. Later the dried specimens may be mounted with long insect pins upon cork sheeting, in cigar boxes, in insect cabinets or lined boxes of commercial make, or in the Riker type of glass-front mounts, without the use of pins. Insect collections should be protected against inroads of destructive forms by being thoroughly treated with gas, such as carbon bisulfide, once each year, and by small bits of moth balls pinned inconspicuously into corners of collection boxes at all times. Many fine school collections have become worthless through lack of attention to this protective technique.

Large Specimens

In preserving large zoological specimens for class use, formalin is usually employed, one part of commercial formaldehyde to eight or ten parts of water. A slit into the body cavity will allow the preservative to penetrate internally, which is essential in large forms, such as rats, birds, or cats. Sometimes an arm or a leg may be intentionally cut off for this purpose, as is often done with radially symmetrical forms, such as starfish. Clams and oysters should be "pegged" by inserting small bits of wood between the valves to keep them apart. After a period of ten days in the killing and hardening solution, your specimens may be withdrawn, washed, and placed in fresh, clean preservative in permanent containers. One should bear in mind the fact that immersing fresh animals in alcohol or formalin solution hardens them, so in order to avoid distortion, they should be arranged as desired before being placed in containers. The latter should have lids wide enough to permit normal withdrawal of the specimen later as desired.

Problems for Group Discussion and Review

1. What is meant by the term "applied" zoology?
2. During what year of the secondary school may zoology best be studied? State reasons for your answer.
3. Describe the basic content and topic sequence of such a course.
4. What should be the fundamental aims of the high school course in zoology?
5. How much "type study" and how much of "principles" should be introduced?
6. What specific problems are involved in collecting field specimens of various types for class study?
7. Discuss the place and proper use of zoological taxonomy in the high school.
8. What working materials would you take with you on a field collecting trip (*a*) to the seashore, (*b*) to a swampy area, (*c*) to a wooded glen?
9. Do you think live-specimen collection and transportation to the laboratory is worth the trouble? Discuss.
10. To what degree is student participation in the collecting and preserving of zoological specimens advisable? Do you consider this form of basic training important? Why?

Chapter 8. CHEMISTRY

Foundational education in the physical sciences demands as prerequisite a relatively high degree of intensive training in specialized subject fields. In presenting the material of modern chemistry, for example, no person may stand with assurance before senior high school students who does not have complete mastery of the intricacies of this science. Factual subject matter is considerably less flexible than in any of the life sciences, rarely permitting substitution, rearrangement, or climatic and regional variation, and being generally less resilient in terms of course of study construction. Competent professional preparation being assumed, subject content, as elsewhere throughout this text, will take second place to evaluation, analysis, type presentation of limited instructional facets, motivation, and correlation.

It will be helpful to trained but inexperienced teachers to indicate some of the salient features which characterize exceptionally competent chemical education at the secondary school level. It will be informative as well as professionally broadening to point out to teachers-in-service the unmistakable trend toward group socialization, in terms of community and industry in peace and in war, which has recently permeated science education at all levels, not only in the elementary and secondary schools, but in our college and university laboratories.[1] Building progressively upon foundational structures established earlier in the science sequence, it may be well at this point to reexamine the developmental sequence of science education as indicated in the teacher-training courses of the institution or, in the case of teachers-in-service, the developmental sequence as established in the urban or rural system. It is of importance that previous training be taken into consideration as the eleventh- or twelfth-grade student enters the chemistry laboratory.

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[1] Payne, Fernandus, "Teaching of Science at the College Level," *Science*, Vol. 111, No. 2892, June 2, 1950.

CRITERIA OF EXCELLENCE

Student Enthusiasm

The first valid criterion of professional superiority in chemistry teaching, viewed in the socializing philosophy advocated throughout these pages, is a notable degree of *enthusiasm* upon the part of students who have enrolled in the class. This spirit of comparative delight in the partial revelation of scientific opportunity stems from a well-defined realization of the essential worth inherent in chemical studies. Creation and maintenance of such an *esprit de corps* in terms of science appreciation naturally presupposes a contagious effervescence and an evangelical, dynamic enthusiasm upon the part of the *instructor,* in addition to quiet competence. Interest in social and commercially advancing achievements of chemistry in terms of betterment of life and living in the world of today and tomorrow must be your avocation as well as your vocation.

It is probable that no instructional activity or phase of chemical science studied in your classroom will permanently remain unused by science. Everything studied has potential or immediate application. The food students eat, the clothes they wear, the things they use, all are influenced in development to an astonishing degree by chemical processes. Chemistry is important in the home, in the community, and in the life of each individual, and an alert chemistry class will show enthusiasm in discussion, experimentation, and in reference research, through realization of this truth.

Manual Skill

A second criterion of teaching ability in this field is the degree of competence in semitechnical manipulation revealed in the laboratory by members of the high school class. The best teachers of all subjects are happy when they are able to help young people learn the tools of a craft, and there is much in the field of chemistry which is difficult to handle well. Skills are important in all sciences, but in chemistry success is quite dependent upon personal ability in the laboratory, where individual investigations are always conducted. When students of secondary school chemistry reach the end of the second semester, manipulative confidence should be consistently apparent. Mastery of method and technique in the handling of reagent bottles and stoppers, glassware, burners and attachments, test tubes, flasks, crucibles, balances, titration equipment, and other paraphernalia of the laboratory should have become ingrained. Synonymously, a habit of orderliness and system in handling and cleaning apparatus, essential for later industrial or collegiate qualitative and quantitative work, should be firmly established. Students enrolled have a right to expect personal experience in handling equipment and supplies, and a carefully conducted laboratory will make ample provision for this training.

Mastery of Fundamentals[2]

A further basis for evaluation is the degree of student mastery of basic truths and foundational facts. It is certainly not the province of a high school chemistry course to incorporate *all* the essentials of inorganic, qualitative, physiological, organic, textile, and physical chemistry within the one-year survey. It is entirely reasonable to assume, however, that students completing a year's course shall have had thorough grounding in the symbolic language of chemistry, in the elements and in compound formation, in equations and their balancing, and in valence. Some attention to the inner structure of atoms (also studied in secondary school physics) is prerequisite to many comprehensions in chemistry.

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[2] In teaching fundamentals today text-films are invaluable. For example, Weaver, Elbert C., and Foster, Laurence S., *Chemistry for Our Times* has correlated filmstrips to accompany the book. Text-Film Department, McGraw-Hill Book Company, Inc., New York.

The periodic table and its modern completion is a fundamental. Distinctions between acids, bases, and salts and between mixtures, solutions, and suspensions; the essential properties of the halogens, the light and heavy metals; and a realization of the significance of compounds of nitrogen, sulfur, and carbon are basic. Chemicophysical constants, such as Boyle's law, Faraday's laws of electrolysis, Charles' law, Dalton's law of gas pressure, Gay-Lussac's law, and Avogadro's hypothesis, should become thoroughly familiar, together with a degree of mathematical competence resulting from steady drill in handling molecular weights and other calculations essential to the pursuit of chemical knowledge and commensurate with the intellectual maturation of high school juniors and seniors.

Up-to-date References

A functionally successful chemistry course insists upon recent reading materials.[3] There is no field of modern science which moves more rapidly than does chemistry. The practicing chemist must keep abreast of his contemporaries or his investigations and reports are of little merit; hence training in the consistent and careful perusal of such periodicals as *Chemical Abstracts* and *Science News Letter* must be an integral part of the course, aiding motivation in scientific thinking while developing desirable attitudes in terms of social consciousness.[4] Research studies have shown that success in college freshman chemistry is based upon two fundamentals developed in the secondary school classroom: an ability to perform basic mathematical calculations, and a reasonable proficiency in the reading and understanding of chemically informative written materials.[5]

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[3] Webb, Hanor A., "Boiled Down Books," *The Science Teacher*, Vol. XVIII, No. 1, February, 1951.

[4] Kinney, Lucien, and Dresden, Katherine, *Better Learning through Current Materials*, Stanford University Press, Stanford, Calif., 1949.

Scientific Method

Another point of judgment is the degree to which the scientific method of approach has been indoctrinated into the behavior patterns of those who are nearing the end of the year's course. The virile chemistry teacher not only gives instruction in processes and in basic skills, but he reveals methods of problem solving which may in truth be adaptable to most of life's situations, as he inculcates in his students the spirit of logical empiricism which characterizes scientific thinking. Employment of tentative hypotheses, or "hunches," as students would refer to them, in formulating possibilities and lines of attack, is standard procedure in chemistry. The period of patient experimentation, the careful analysis to reveal possible causes of error, and the tenacity shown in exploration of all interrelated data essential to the proving or disproving of the validity of an original idea are all applicable to the daily life of every chemistry student.

Much transfer value (using the term in its larger sense) may be claimed for laboratory science in general on a basis of pragmatic approach embodying individualized problem analysis and manipulative experimentation. The setting up of hypotheses and procedures followed by the basing of conclusions upon observed phenomena and accumulated substantiating evidence, which characterize chemistry, are of more than temporary worth in preparing young people for higher education, for the probability of industrial promotional progression, and for leadership as well as intellectual respect in citizenship.

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[5] Jackson, Robert, "The Selection of Students for Freshman Chemistry by Means of Discriminatory Functions," *The Journal of Experimental Education,* Vol. 18, No. 3, March, 1950.

Practical Emphasis

The socially functional chemistry course must be practical in terms of human need. Subject matter is closely correlated with the life and work of citizens of the community, just as industrial leadership today is inseparably dependent upon the research laboratory and testing ground for trial chemical plants, new and better processes, and the experimental scientific groundwork essential for continued commercial dominance in any given field. The situation may indeed be thought of as analogous to that of the university professorship, research and interpretative instruction being quite inseparable in higher education. General Motors, for example, has tabulated 256 chemical products actually used in the American automotive industry, more than 30,000,000 pounds of plastics alone being consumed in the manufacture of automobiles in a normal peacetime year.[6]

The best way of bringing about student realization of community-school-industrial interdependence is through curricular emphasis upon field excursions. There is scarcely a community of any size in America which does not provide functional demonstration of the practical adaptation of chemistry, if the instructor is alert to environmental opportunities.[7] Emphasis upon the practical in secondary schooling bears rich fruit, the taste of which may linger throughout a lifetime. The author still vividly recalls almost every detail of a class visit to a glass factory, conducted by his own high school chemistry teacher more than a quarter of a century ago. It is highly probable that other lessons of undoubted value were taught by this most respected instructor, but in the perspective of time and distance, that group field trip to the glass factory remains indelible as an impression of a group of men actually working in applied chemistry!

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[6] McCuen, C. L., *A Research Man Speaks,* General Motors Corporation, Detroit, 1950.

[7] Oliver, A. I., "The Objectives of a Small High School's Philosophy," *The School Review,* Vol. 58, No. 3, March, 1950.

The technical skills of chemists are not related to urban life alone. If anything, the reverse is true, for the affinity of chemurgy to forest and agricultural production in such areas as paper pulp from pine trees and paints and varnishes from soybean oil is well known. Application of chemistry to problems of rural communities is exemplified by research demonstrating increased growth-weights in hogs, sheep, and dairy cattle when *cobalt* and other elements are added to the diet.[8] Apparent interrelationship of chemical know-how to the practical needs of the community will motivate student interest and enthusiasm, making problem solving and routine recording of procedures and results seem worth while from the point of view so prevalent among youth: "What good is it? Why should I study chemistry?" Illustrations of applied use are legion. Let us examine others at this point, in order to give indication of the breadth of coverage involved.

For example, one need not be a university man in order to profit from chemical reaction. Oyster fishermen operating in Long Island Sound, until a few years ago, found their losses to starfish amounting to a million dollars a year in that area alone. A century of trial-and-error effort had brought no effective solution until government chemists suggested a simple spreading application of quicklime under water, which acted upon starfish tissue, destroying these carnivorous echinoderms in cheap and practical fashion, while having little injurious effect upon the oysters.[9]

A more recent illustration of practical chemistry in service is the phenomenon of rain making through artificial nucleation of clouds, making the innumerable droplets of moisture come together until they are heavy enough to cause measurable precipitation. Silver iodide is a compound used in field nucleation practice, being spread through cloud formations by airplane or by the use of ground generators.[10]

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[8] Klosterman, Earle W., Dinusson, W. E., Lasley, Earl L., and Buchanan, M. L., "Effect of Trace Minerals on Growth and Fattening of Swine," *Science*, Vol. 112, No. 2902, Aug. 11, 1950.

[9] U.S. Department of Interior, Research Report No. 2, *Use of Lime in Controlling Starfish,* U.S. Government Printing Office, Superintendent of Documents, Washington 25, D.C.

CHEMISTRY AND HUMAN WELFARE

A medical instance may be introduced in order to demonstrate further the extreme variety of practical application of chemical knowledge for human betterment. Much research has been pointed in recent years toward possible cancer causes, treatments, and cures, the collective problem of cancer as a killer of human beings challenging the very best intelligence and the most painstaking application of the methods of science. The only accepted facts at this writing are that normal cells in some manner begin to grow wildly—sometimes quickly, sometimes slowly, producing abnormal invading growth which features rapid mitosis of cells. Constant chemical or mechanical stimuli are believed to produce malignant development, particularly if hereditary symptoms are favorable. The malignant cells may be killed, if treated in time, by radiation with radium or X ray, or they may be removed through surgery.

Chemistry enters the picture through varied attempts at locating some causes, as well as potential cures. Tatum and Griffin of Stanford University have shown that nitrogen mustard compounds produce cellular changes in rats and mice which lead to cancer, for example. Human cancer chemotherapy now employs aminopterin and a-methopterin plus a citrovarum factor in many clinical centers. Aminopterin and its allied chemicals, although toxic, have been shown to be effective with leukemia, and the addition of citrovarum moderates the toxicity.

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[10] Langmuir, Irving, "Control of Precipitation from Cumulus Clouds by Various Seeding Techniques," *Science*, Vol. 112, No. 2898, July 14, 1950.

Skin cancer, produced through prolonged exposure to strong sunlight while sunbathing, or occasionally through the unsupervised use of ultraviolet face radiation, is being successfully attacked through biochemistry. Skin cancers generally metastasize slowly or not at all, providing time

FIG. 17. *Youth looks at cancer.* Demonstrations of such unobjectionable forms as skin cancer in its early stages of cure by X-ray radiation are of definite benefit in socializing physical science education. Individual enlightenment is the crux of cancer education, facilitating early detection and prompt treatment. (*Cover photograph from the booklet Youth Looks at Cancer, produced by the Westchester Cancer Committee of Bronxville, New York.*)

for detection and radiation therapy or surgery. Dermatologists have found colchicine to be effective when injected directly into cutaneous carcinomas, the chemical seemingly halting cellular mitosis.[11] Clinically, some cases reappear, while others (over a five-year observation period) seem to be definitely arrested, hence the chemotherapy is still experimental. Both aminopterin and colchicine are extremely promising in terms of biochemical research in this vital field.

As a further development of the single medical instance of the relationship of research in chemistry to cancer, we may point to a startling new technique of "chemosurgery," involving the use of a fixative paste which kills and hardens malignant tissue while stopping bleeding, so the surgeon may probe for cancerous tissues cleanly, with the result of total removal in most skin cancer cases, a minimum of consequent plastic work being necessary. Chemistry is, indeed, the ally of medicine in striving to provide for human welfare.

The radioactive isotopes of cobalt, phosphorus, and iodine have further demonstrated the practical applications of chemical substances. Phosphorus is used in locating brain tumors, while radioactive iodine, being absorbed by the thyroid, acts to aid in locating and destroying thyroid gland tumors in the throat. Another interesting example of medical use for a chemical compound is the employment of ammonium sulfate as a control agent for pain transmission in the spinal cord, through injection into the spinal canal. Introduction of fluorides into community drinking-water sources and the common use of ammoniated tooth powders and pastes are noteworthy additional illustrations of chemistry applied to social betterment, being particularly effective in reducing the incidence of dental caries among adolescents in our junior and senior high schools.

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[11] Nelson, Lawrence M., "Effect of Locally Injected Colchicine on Cutaneous Carcinomas," *American Medical Association Archives of Dermatology and Siphilology*, Vol. 63, No. 4, April, 1951.

Of the many examples of ways in which chemical knowledge is being brought to bear upon problems related to human welfare, however, none is more promising or more far-reaching in humanitarian terms than the development of glutamic acid, one of the "building blocks" of the human body, the amino acids. Increased physical and mental vigor noted when glutamic acid is administered to subnormal children, even of the "mongol" type, and to preadolescent young people of the low-I.Q. type, is one of the biochemical and educational marvels of our modern scientific age. Epileptic cases are being controlled and intelligence-quotient ratings sent soaring under the administration of glutamic acid, which influences the central nervous system, to the delight of parents and teachers, as well as of physicians and chemists.

Chemotherapy goes beyond medical employment with humans, being widely adaptable to a great host of plant and animal pathologic conditions which have baffled botanists, entomologists, and pathologists for years. "Dutch blight," for example, a fungus which in the past has killed literally millions of beautiful elm trees throughout the nation, is today being controlled through base feeding of carolate and 8-hydroxy-quinoline benzoate through the root systems, the chemical antitoxins making treated elm trees practically immune. An antibiotic (cycloheximide) has been shown to control powdery mildew of beans when applied as a spray and, in proper dilution, is effective on cucumber scab and cherry-leaf spot, both dangerous fungi.[12]

DDT has been known for some years as an insect-pest control agent, having been developed during the Second World War. Another coal-tar derivative, "methoxychlor," is a recent addition to the group of insect-killing agents, and has shown exceptional ability to do the job required, with extremely low toxic effect upon plants, as well as upon people, animal pets, and dairy cattle. 2-4-D (2-4-dichlorophenoxyacetic acid), the most promising weed killer so far developed by chemical research, has proved extremely effective on such troublemakers as poison ivy, poison oak, morning-glory (bindweed), and ragweed.

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[12] Stout, Gilbert L., "New Methods of Plant Disease Control," *Bulletin of the California State Department of Agriculture*, Vol. 39, No. 3, September, 1950.

Numerous other contributions made by chemistry may and should be cited by the alert teacher, for chemistry makes its greatest mark in terms of social living.[13] Practically all foodstuffs and farm products have been experimented upon in research laboratories devoted to applied science, most of these having been changed to greater or less extent into new substances, of related value to man. The enormous field of *synthetics* is comparatively modern, in which such farm products as corn and oats have been miraculously transformed into paper, dyes, buttons, face powders, and kindred items; milk into wool; and milk casein into glue, sizing, and various plastics. The lowly soybean, little known until recent years in the occidental world, forms a base for the production of paint, linoleum, ink, and even candy.

The work of George Washington Carver, the Negro chemical analyst, who practically singlehanded turned much of the southern portion of our nation from a one-crop, cotton-producing, slowly starving land into a commercially thriving area through crop rotation and the chemical study of peanuts, is in itself an object lesson in applied social chemistry. One of the prime objectives of every teacher of secondary school chemistry must be to stress these practical outcomes of scientific research, for such studies not only provide impetus to individual and group participation in discussions of lasting merit but embody the essence of respect and reverence for scientific tenacity and inspired revelation through chemical research, which has resulted in the unlocking of a few of the many doors leading to solutions of current problems.

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[13] For a masterful summary, see Pauling, Linus, "Chemistry," *Scientific American,* Vol. 183, No. 3, September, 1950.

Chemurgy, the scientific practical application of chemical technology to the processing of land products and other raw materials for use as food or for noncaloric processes of man, has added tremendously to our national wealth of "creatable resources." Industrial alcohol produced from grains has been developed as an antiknock fluid additive to gasoline. "Corn steepwater" and lactose are now providing the nutrient materials for the laboratory growth of *Penicillium notatum* and other important molds. Chemists in oil refineries and experimental stations have produced additives which clean the automotive engine as it runs, prevent corrosion, act as antioxident agents, shorten the life of oil foam bubbles, and reduce carbon and sludge deposits in lubricating oils. New oils, "the product of atomic energy," ap-

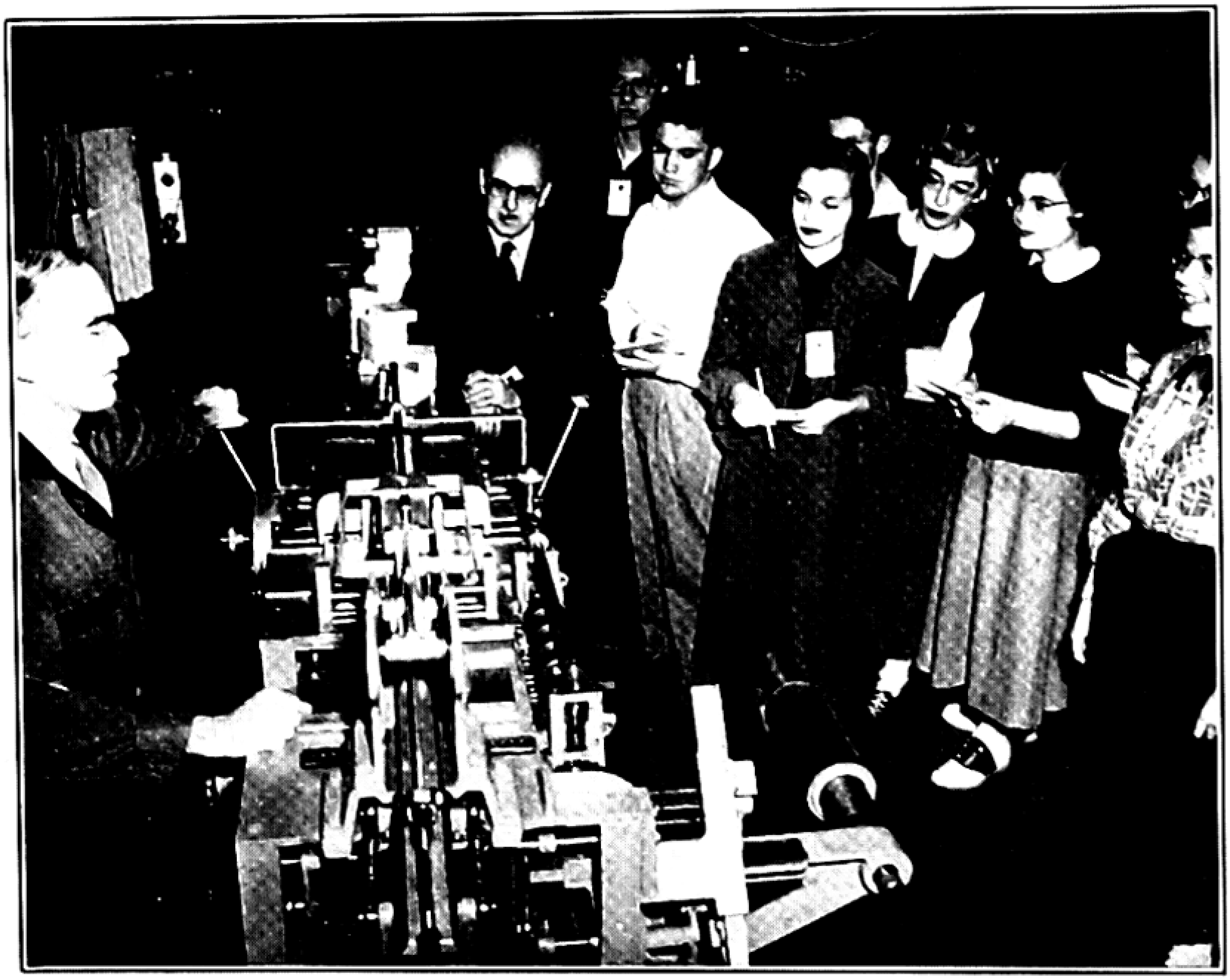

FIG. 18. The high school chemistry class observes operation of a wrapping machine dispensing a new plastic-film product useful in human food preservation. (*Photograph courtesy of the Dow Chemical Company.*)

proximately double the life of American automobile engines. Through applied petroleum chemistry, one of the most promising fields entered by graduating chemists today, it has become practical to produce gasolines, oils, and greases tailored to individual specifications and needs.

LIFE-SCIENCE CORRELATION

The outstanding course in eleventh- or twelfth-grade chemistry will show correlation with life science in many ways, as one result of emphasis upon the practical phases of chemical technology. The philosophy of integration of physical and biological sciences[14] (physics and chemistry on the one hand and biology, physiology, botany, and zoology on the other) has attained significant status in graduate university circles.[15] No person obtains the full Ph.D. in either field today without a degree of interchange at the graduate level in *both* disciplines. It is important to realize this fact and to see that our students realize it.

All matter (physically analyzed in the chapter which follows) is composed of chemical elements, usually in combination, water and salt being common illustrations within animal bodies. The early assumption of "organic" compounds as being present only in living organisms, and the illuminating synthesis of urea by Wohler in 1828, resulting in the subsequent correlation of hydrocarbon chemistry with human progress, make ideal discussion topics and research problems of interest to the secondary school class.

Malaria is listed by the United States Department of Public Health as *the* world-wide health problem of greatest import, for this disease kills more human beings throughout the world than does heart disease, cancer, or any other known disease. There are more than 100 million annual cases reported in India alone, of which nearly a million are fatal. The transmission of malaria by the *Anopheles* mosquito is well known, scientists having been at work in attempts to remove possible breeding places for many years. When the Japanese cut off the greater portion of the world supply of quinine at the beginning of the Second World War in the Dutch East Indies, the war in the south Pacific seemed lost to us before well begun, for humans cannot wage war in the tropical jungles without immunization against malaria. Allied biochemists, however, quickly introduced "atabrine," which saved many American and Australian lives and made warfare in the south Pacific possible. Later development of "plasmoquin," "chlorequin," and "oxychlorequin" provided chemical agents twice as effective as atabrine. Chlorequin and oxychlorequin are nonpoisonous and may be taken one each week, instead of every day. The medical world, thanks to chemical skill, will never return to quinine, today outmoded as a preventative or cure for malaria.

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[14] Refer to discussion in Chap. 2, Science and the Scientific Method.

[15] A significant example is Casperson, Torbjoern O., *Cell Growth and Cell Function*. W. W. Norton & Company, New York, 1950.

Similar studies and socialized reports may be made by individuals and groups of students with relation to the world supply of natural rubber and the Japanese strategy of action in the Second World War. America is a nation on wheels, and the cutting off of our supply of natural rubber for automobile and truck tires at that time meant only one thing: that American economy and military power would slowly but surely grind to a halt and America would be helpless. Chemical research again came to the rescue with synthetic rubbers, and American industry as well as mobile transport was saved. The synthetic chemical industry, as we have seen in the present chapter, has developed tremendously since the last war.

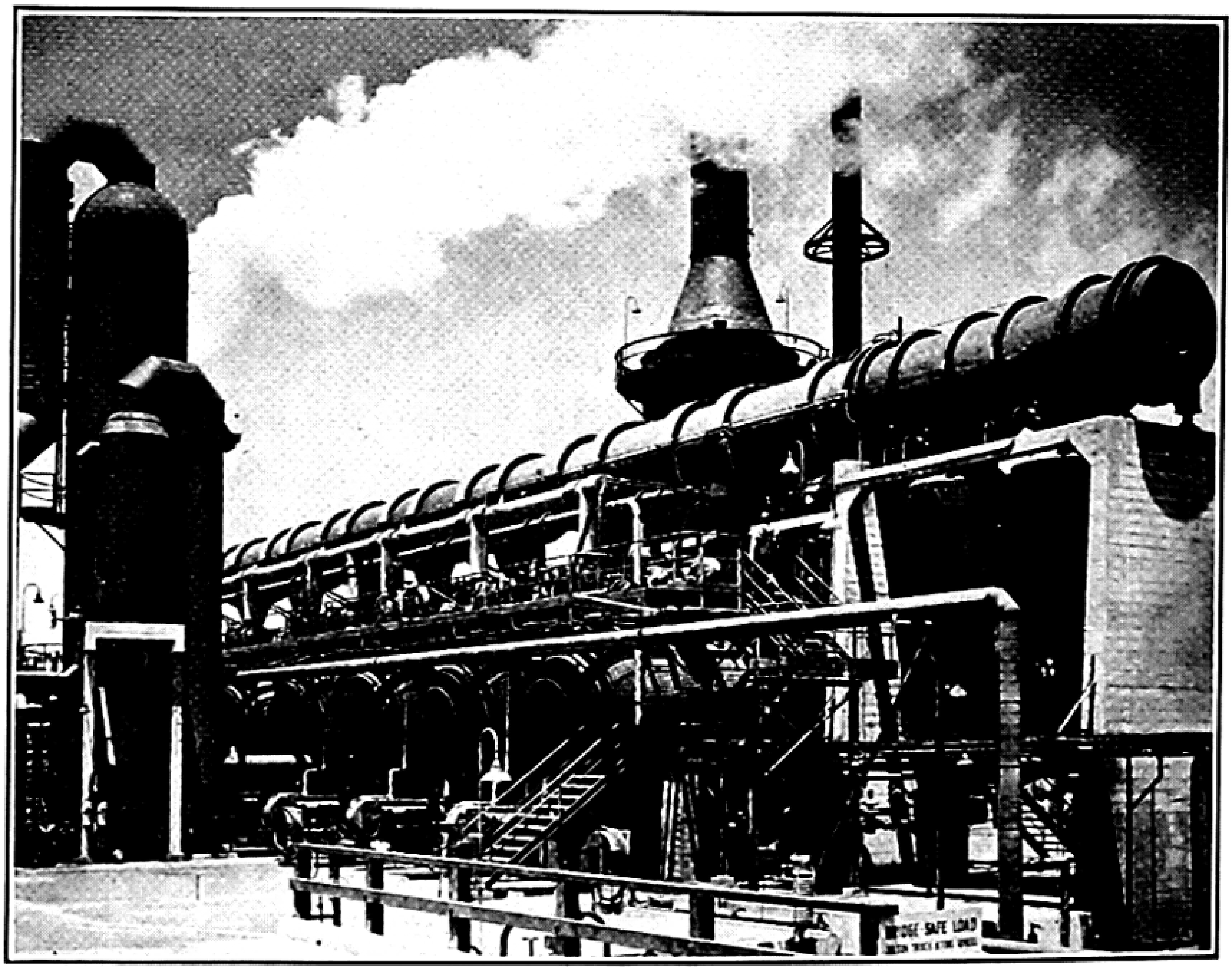

FIG. 19. A commercial plant for the manufacture of butadiene rubber. Rapid commercial adoption of this chemical process for the production of synthetic rubber was a vital factor in keeping America "on wheels" during the Second World War. A class visit to such a plant would provide a lifelong lesson in applied chemistry and simultaneously supplement the work in social science. (*Photograph courtesy of the Standard Oil Company of California.*)

TYPE CONTENT MATERIAL

The basic considerations of *biochemistry* provide a phase of chemical knowledge and present-day university research which should be prominently featured in secondary school instruction; hence, its biological correlation will be analyzed as a type unit of study in some detail. An introduction to the study of proteins, carbohydrates, fats, blood chemistry, and the life substance itself form minor units which will prove of real interest to young people, and which may be presented to a degree not overdifficult at this stage of maturation.

PROTEINS

What should we emphasize in protein chemistry, for example? Egg albumin is a protein; grain gluten, bone gelatin, and milk casein are proteins; let us have investigations and group reports on them. Where do they come from? What can chemists make out of them? Many proteins, notably the hemoglobin present in our red corpuscles, are important in our consideration of animal-body chemistry. Investigation will reveal that, in addition to carbon, hydrogen, and nitrogen, proteins contain sulfur, oxygen, and sometimes phosphorus, grouped into "amino acids," of which the glutamic acid previously described in this chapter is one. The instructor may point out that these chemical associations, such as glycine, histidine, lysine, and threonine, represent examples of fairly complex protein substances.

Protein Individuality

One interesting consideration which may well be brought out during your presentation is the fact that proteins of any given plant or animal have long been known to be unique and constant for each organism. This "protein individuality" has been utilized in blood transmission; laboratory technicians ran comparative tests on blood samples of prospective donors, to determine whether corpuscles behaved similarly. In many cases, corpuscle grouping (agglutination) was held responsible for early fatalities in transmission of incompatible bloods between humans. Blood transmission from one vertebrate type to another may be fatal; blood from cats, for instance, producing disastrous results if mixed with that of humans. Resultant contributions of eager young investigators will bring out the fact that it is the protein content of blood which is responsible, protein individuality conferring identity upon plant and animal tissues.

Blood Typing

Actually there are two factors to be considered in the matter of agglutination: the so-called "agglutinogens" of the corpuscles and the "agglutinins" of the blood serum itself. Modern human blood typing concerns itself with four principal groups of these, namely, "A," "B," "AB," and "O," each with varying arrangements of agglutinin and agglutinogen. Further, human red corpuscles have what are referred to as "M" and "N" agglutinogens. There is also an Rh factor involved in about 85 per cent of white persons' blood, named from its discovery in the monkey *Rhesus,* probably a protein modification.

In addition to whole human blood, plasma or plasma fractions are often used today, both in peace and in war, the proteins of dried-out frozen plasma remaining functionally intact for years. The principal reason blood plasma is preferred today is that mixture of plasma from many persons dilutes the agglutinins mentioned, so that their distinctive individuality is not effective. In the second place, when blood plasma is used, there are no red corpuscles to agglutinate. Addition of distilled water to the flakes of dried plasma, either by the medical corpsman on the battlefield or by the laboratory technician in the urban hospital, makes fresh whole blood. Other research-developed proteins include isolated fractionated "globulins," used in treatment of measles; "albumin," a substitute for dried plasma; and "thrombin," which aids in blood clotting.

Color Reactions

The color reactions are interesting to high school students and should be a definite part of your course as illustrative of qualitative procedure in identification of protein in familiar substances. Perhaps the most commonly used of these reactions is the "xanthoproteic" test, wherein concentrated nitric acid (HNO_3) is added cautiously to the substance in question. Either immediately or upon the application of heat, a yellow color indicates the apparent presence of protein. If, upon cooling, the addition of ammonium hydroxide (NH_4OH) along the walls of the test tube (inclined in such a manner that the NH_4OH comes to rest in a layer above the nitric acid-treated substance) produces an orange color as the alkaline layer meets the acid, definite assurance that the substance tested contains protein is given.

A specific word of caution must be given here regarding the use of strong chemicals, such as concentrated HNO_3, by eleventh-grade pupils. Either be very sure of the steady nerves of your student demonstrator or do the demonstrating yourself. Personally, the author invariably handles all such demonstrations involving strong acids or bases, from the lecture platform in the secondary school. It is the only wise and safe method.

The well-known "Biuret" test for protein is another color reaction often employed in chemical laboratories. In this qualitative determination, sodium hydroxide ($NaOH$) is added to a solution containing the dissolved substance, or (if it is insoluble) to a suspension containing the insoluble substance. Very dilute copper sulfate solution ($CuSO_4$) is then added slowly, drop by drop. A violet color reaction demonstrates the presence of a protein. In case of the absence of protein, a negative action is shown by the gradual assumption of the characteristic blue color of the copper sulfate, quite different from the positive violet reaction, however faint the latter may be.

"Millon's" test is the third of the trio of commonly employed reactions we are here detailing as types. The substance to be tested is boiled with "Millon's reagent," and if protein is present it is precipitated out as a reddish-colored solid during the process.

Occasionally, owing to the complex molecular variations indicated in working with the many and various proteins, one of these classroom color tests will work, where another will not. A negative reaction with one of these, therefore, does not give positive assurance that no protein substance is present, but rather that protein of the general type which the test is designed to reveal is lacking. While the presence of a protein may be indicated by any of these tests, positive assurance that protein is lacking is obtainable only after securing negative reactions in all three.

CARBOHYDRATES

We know that there are two basic types: the sugars and the starches. Beginning chemists are quite generally under the impression that sugar is "sugar," and that starch is "starch." However, as you will show, there are several kinds of each. For example, demonstrate that cane sugar is derived from the stalks of sugar cane, beet sugar from the roots of sugar beets, maple sugar from the trunks of maple trees, and lactose from milk. In like manner, show that corn, rice, wheat, potato, and arrowroot starches typify sources of this carbohydrate. In the chapter on Physics which follows, considerable attention is given to the subject of energy transformation, and this topic may need elaboration in the chemistry class at this point.

Sugars

These are outstanding physiologically as being subject to rapid oxidation; in other words, we know that they "burn" as fuel rapidly and that hence, as a group, they constitute energy quickly convertible from potential to kinetic. Being soluble, they are easily transported through the tissues of plants and animals, while comparatively insoluble starches are commonly stored as food. In plants carbohydrates are stored in roots, stems, tubers (underground stems), nuts, and fruits, as well as in the endosperm or cotyledons of seeds. In animals, carbohydrate food energy, accumulated in the form of glycogen, is stored in the liver and in the muscular system.

Glucose (grape sugar), as well as lactose (milk sugar), may be identified in the laboratory by means of Fehling's test. Two solutions are used, one colorless, one blue. To the substance to be tested, equal amounts of the two solutions are added, and the resulting mixture is heated to boiling. If glucose is present, a brick-red precipitate will be thrown down as the solution reaches the boiling point. Cane and beet sugars will not react in this way, giving a negative reaction when heated to boiling with Fehling's solutions.

Starches

Color tests on starches may easily be run by beginning students, being identified by the simple but sensitive iodine reaction. Iodine solution (metallic iodine flakes and potassium iodide in alcoholic solution) is dark brown in color. When added to any substance containing starch, it turns a deep blue. If an excess of starch is present, the resultant color may be so blue as to appear almost black. Very minute amounts of starch, brought into solution by heating, may readily be detected in this manner.

FATS

Fats and oils classed as fats are widely distributed throughout plant and animal bodies. In general, surplus food material of the fatty type over and above the current energy need for the organism is stored away as potential energy, much as are the carbohydrates. Fats are much slower to oxidize than are the carbohydrates, however, and consequently are used up more slowly. In animals, a layer of protective fat protects against excessive loss of bodily heat, besides serving as cushioning material for delicate organs, such as the eyes. Mammals ecologically adapted to cold regions—the walrus and the whale, for example—utilize this high-quality insulation in the maintenance of body temperature. Besides the fatty meats eaten by human mammals, lard and butter are examples of animal fats. Among plant fats may be listed linseed, cottonseed, and olive oils, as well as the oil from such nuts as walnuts and almonds, or from such fruits as avocados.

Tests for the presence of fats in unknown substances which may be individually run by students are of two common types, both being mechanical rather than color reactions. If the substance is a liquid, ether or carbon tetrachloride may be added and thoroughly shaken up with the liquid, in order that the fatty substance, if any, may become dissolved in the solvent. The latter is then poured off into a receptacle and permitted to stand, evaporation of the solvent leaving a layer of fat as residue if fat was present in the original unknown.

If the substance to be tested is a larger solid, it may be rubbed on ordinary wrapping paper by the students. If the paper becomes translucent, the presence of fat is indicated. Note, in your classroom instructions accompanying this type of lesson, that the word is not "transparent," as most students will say at first. These qualitative food-indicator tests, involving work with "unknowns" (always interesting procedure at the high school level), have been presented in some detail in these pages as an indication of type content adaptable to life-science integration in the socialized chemistry class.

PROTOPLASM

The life substance itself may be studied in the chemistry class, for chemical elements comprise living as well as nonliving matter. As we have seen, best results in terms of long-range comprehension will be obtained through coordination of the concepts of both the physical and life sciences. The life substance which makes up the bodies of organisms, both plant and animal, has been found to be composed chemically of four principal elements: oxygen, carbon, hydrogen, and nitrogen. The percentage composition is approximately as follows:

Oxygen	65 per cent
Carbon	18.5 per cent
Hydrogen	11 per cent
Nitrogen	2.5 per cent

The remaining 4 per cent we know to be formed of compounds containing calcium, sodium, iron, phosphorus, chlorine, sulfur, iodine, potassium, and other chemical elements in minute amounts. That the living human-animal organism, the student's own body, is thus chemically compounded is one of the important concepts of this secondary school age of maturation. The chemical affinity in composition between cat and mouse on the one hand, and tree and grass on the other, is a further developmental realization.

We must continue to bear in mind, as we conclude our professional survey of the broadening and deepening field of secondary chemical education, that these are adolescent girls and youths we are instructing. Our efforts will prove of lasting worth if we pave the way, if we build for appreciation, if we provide motivating stimuli, if we teach the method of observation, result, and conclusion. Our work will not prove to have been worth while if we strive to impart collectively into young heads a great mass of chemical knowledge, per se. Much depends upon selection and evaluation of content material. If vitalized subject matter is presented in logical and clear sequence, and if emphasis is placed upon the social significance inherent in such studies, student reaction and carry-over will be excellent.

With these indications regarding points of emphasis, interpretation, and correlation, the author presents in culmination a basic-type outline for an adequate course in eleventh- or twelfth-grade chemistry. It is expected that variations, additions, and subtractions will be made within limitations of chemical boundaries, in accordance with the inclination, specialized training, and professional experience of each educator, as well as with the comparative intelligence and collective diligence of his class.[16]

COURSE OUTLINE FOR CHEMISTRY

Unit I. "What Is Chemistry?"
  Definitions. Why the study of chemistry is important.
  The history of chemistry, from Priestley and Lavoisier to the present.
  Chemistry today and tomorrow. Present accomplishments and future possibilities.

Unit II. "Basic Concepts of Matter and Energy. Chemical and Physical Change."

Unit III. "The Chemical Elements."
  Carbon, oxygen, hydrogen, nitrogen, and the other more common elements.
  Chemical symbols and properties of the elements.

Unit IV. "Compounds and Compound Formation."
  Water, hydrogen peroxide, carbon monoxide, carbon dioxide, starch, sugar, and other comparatively simple compounds.

Unit V. "Mixtures, Solutions, Suspensions, Crystallizations."

Unit VI. "Valence and Its Use. Balancing Chemical Equations."

Unit VII. "Atoms and Molecules. Basic Structural Facts."

Unit VIII. "Gases and Their Properties."
  The gas laws.
  Concepts of pressure and volume.

Unit IX. "Acids, Bases, and Salts."
  Ionization and behavior.

Unit X. "Electrolytes and Their Reactions."
  Salt solutions. Conductivity.

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[16] For exemplary demonstrations, laboratory experiences, and projects, see Richardson, John S., and Cahoon, G. P., *Methods and Materials for Teaching General and Physical Science*, pp. 418–471, McGraw-Hill Book Company, Inc., New York, 1951.

Unit XI. "Metals and Their Compounds."
  Ore sources and extraction methods.
  Copper, silver, gold, tin, lead.

Unit XII. "Organic Chemistry Fundamentals."
  Carbon and its compounds.
  Alcohols.
  Aldehydes.
  Ketones.
  Acids.
  Esters.
  Fats (including food-identification tests).
  Carbohydrates.
    Sugars (including food-identification tests).
    Starches (including food-identification tests).
    Cellulose derivatives.
      Plastics, cellulose acetate, cellulose xanthate.
  Proteins (including food-identification tests).
    Simple, conjugated, and derived proteins.
    Elements of blood-protein chemistry.
      Blood typing and blood-plasma banking.
      Uses in peace and in war.
  Alkaloids.
    Nicotine, atropine, quinine, strychnine, morphine, codein, cocaine.
  Dyes. Synthetic and natural dyes. Utilization in industry.
  Resins. Synthetic nylon and rubber.
  Turpenes (camphor) and essential oils (menthol).
  Vitamins. Types, sources, uses.
  Hormones. Types, sources, uses.
  Enzymes. Types, sources, uses.

Unit XIII. "Radiation Chemistry."
  Correlation with biology and botany in photosynthesis.
  Principles of photography.
  Ultraviolet light.
  Photoelectric cells.
  The spectroscope and its work.
  X rays and radium.
  Radioactivity in chemistry.
    Radiation in photobiology.

Radioactive isotopes in biology and in medicine.
Radioactivity as a future field of specialization.

Unit XIV. "Nuclear Chemistry."
Fundamentals of atomic fission from the chemical viewpoint.
Nuclear chemistry as a future field of specialization.

Culmination Surveys.
Chemistry in industry.
Chemistry in the community.
Chemistry in the home.
Chemistry of modern warfare.
Chemistry of tomorrow.

PROBLEMS FOR GROUP DISCUSSION AND REVIEW

1. In what ways does the technical material handled by the senior high school teacher of chemistry differ from that in eighth- or ninth-grade general science?
2. What criteria may be considered valid for judging proficiency in instruction of secondary school chemistry?
3. Discuss the criteria presented, in terms of basic objectives.
4. What two primary strategic materials were cut off from America by the Japanese at the beginning of the Second World War? What role did chemistry play in bringing about ultimate victory, in terms of these materials?
5. Outline some aspects of protein chemistry you consider desirable for inclusion in the high school course.
6. Outline some aspects of synthetic chemistry you would include in the course. Would you include rayon? Casein plastics? Soybean derivatives? Peanut products? Cellulose products?
7. Do you approve the emphasis upon qualitative unknowns (fat, protein, starch, glucose tests) in the high school course? Discuss.

8. What is the chemical composition of protoplasm? Discuss the subject correlations involved.
9. The course outline as presented, the chapter on chemistry, and in fact the entire text on methods leans to the social viewpoint. What do you think about this, in terms of secondary education?
10. Prepare your own topical outline for a course in high school chemistry, for presentation before the group. In what ways do you believe your outline to be superior? Why?

Chapter 9. PHYSICS

Much of what has been presented in the previous chapter with regard to secondary school chemistry applies in like manner to senior physics, since aims and objectives are similar in both these physical sciences. The laws of physics underlie our daily lives to a remarkable extent, for no organism can exist without constant exposure and reaction to physical stimuli. Recent revolutionary discoveries in both chemistry and physics, furthermore, comprise phases in the science education of American youth which offer limitless opportunities for motivation and sustained interest.

Considered in retrospect, the marvels of achievement in physical science within the last one hundred and fifty years are themselves indicative of interpretative potential in high school physics. The sewing machine, steam engine, friction match, telephone, telegraph, electric light, gasoline engine, airplane, stratoliner, and convertaplane are but a few of the investigation topics available. Others include the radio, television, talking and colored motion pictures, the X ray, radar, automobile sealed-beam headlights, polarized light, air conditioning, electric refrigeration and "deep freeze," electron microscopes, flying wings, and "sky hook" meterological balloons. The 200-inch mirror of the great Palomar telescope searches the heavens in the ceaseless quest for truth and physical phenomena which will supply further data for still further quest for truth.

In the field of national defense, the comparatively recent development of fighter and bomber jet propulsion, radio-controlled supersonic missiles, atomic artillery shells, and atomic-powered submarines render all other types obsolete.

At least one atomic plane is actually in process of experimental construction, which in theory could fly eighty times around the world on a pound of fuel. Scientists now speak of the possibility of floating platforms 200 miles above the earth, electronically controlled from below, in terms of ultimate world military dominance and the maintenance of world peace.

Motivation

Invention pyramids upon invention as pure research in physics is applied to contribute to the happiness and well-being of mankind. Training for life in the world of today and tomorrow cannot proceed without groundwork in the basic principles of physics,[1] if we are to educate in the sense of comprehension and scientific stimulation. Men walk along the street looking for leaks in gas mains, carrying mysterious boxes in their hands and with earphones on their ears. City taxicabs commonly have two-way radio transmission, modeled after the "walkie-talkies" of the Second World War. Prospectors search for uranium ore, using the new physical tool of mineralogy, the Geiger counter. Color television is a reality, and "videognosis" (medical diagnosis at a distance through the use of X ray plus television) has been successfully demonstrated at maximum television range. Hundreds of simultaneous telephone conversations are made possible through the use of microwave transmitters and receivers. Voices, music, and voice personalities are recorded on strips of wire. Phonograph records play for long periods without changing. Radar networks are set up to warn of approaching aircraft. Diesel locomotives haul a hundred fully loaded freight cars up inclined grades with apparent ease. Truly we are living in a physical as well as in a chemical age of discovery and invention.

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[1] Basic physics principles may be motivated through the use of visual aids, sources of which are listed in Part II, Resource Aids, Audio-Visual Instructional Materials. For example, the *Physics Demonstration Series*, Text-Film Department, McGraw-Hill Book Company, Inc., New York.

Early realization of the interdependence of chemistry and physics, together with their demonstrable interrelationship with living organisms and their products, may well form an integrating nucleus of our secondary school teaching. Chemists create new substances out of familiar materials and unused by-products, while physicists make possible the machines which manufacture the creations commercially and harness the power essential for production and distribution.

Problems involving natural laws must be mastered in the process of the application of theoretical physics to applied need. Atmospheric pressure,[2] for example, must be understood as a basic preliminary to the solving of problems in aerodynamic design, exemplified by modern pressurized cabins of stratoliners in transcontinental and transoceanic flight, jet planes, and rocket propulsion through space. Chemurgy plus applied physics has given us "cold" rubber, plastics, and many forms of synthetics.[3]

Industrial Cooperation

An additional factor in high school science subject motivation is the impetus given through such commercially sponsored activities as the "national science talent search" directed by the Science Clubs of America and financed by the Westinghouse Educational Foundation, the George Westinghouse scholarships for high school boys, and the Westinghouse Farm and Home Electric Contest for 4-H Club boys and girls. Parenthetically, note should be taken in this connection of the fifty annual summer fellowships for *teachers* of science offered by Westinghouse at Massachusetts Institute of Technology.

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[2] See Branwein, Paul, "How One Teacher Does It," *The Science Teacher*, Vol. 17, No. 2, April, 1950.

[3] Condon, E. U., "Contemporary Science," *New Republic*, Vol. 122, No. 7, Feb. 12, 1950.

Other commercially sponsored stimulative cooperative efforts which should be mentioned are the General Electric scholarships, as well as the Bausch and Lomb Honorary Science Award and Science Scholarship Program. By means of these industrial-educative stimulants, the gap between classroom and industry in the community is steadily being lessened.[1] Beneficiaries of such cooperative programs include industry, professional educational institutions, and the stu-

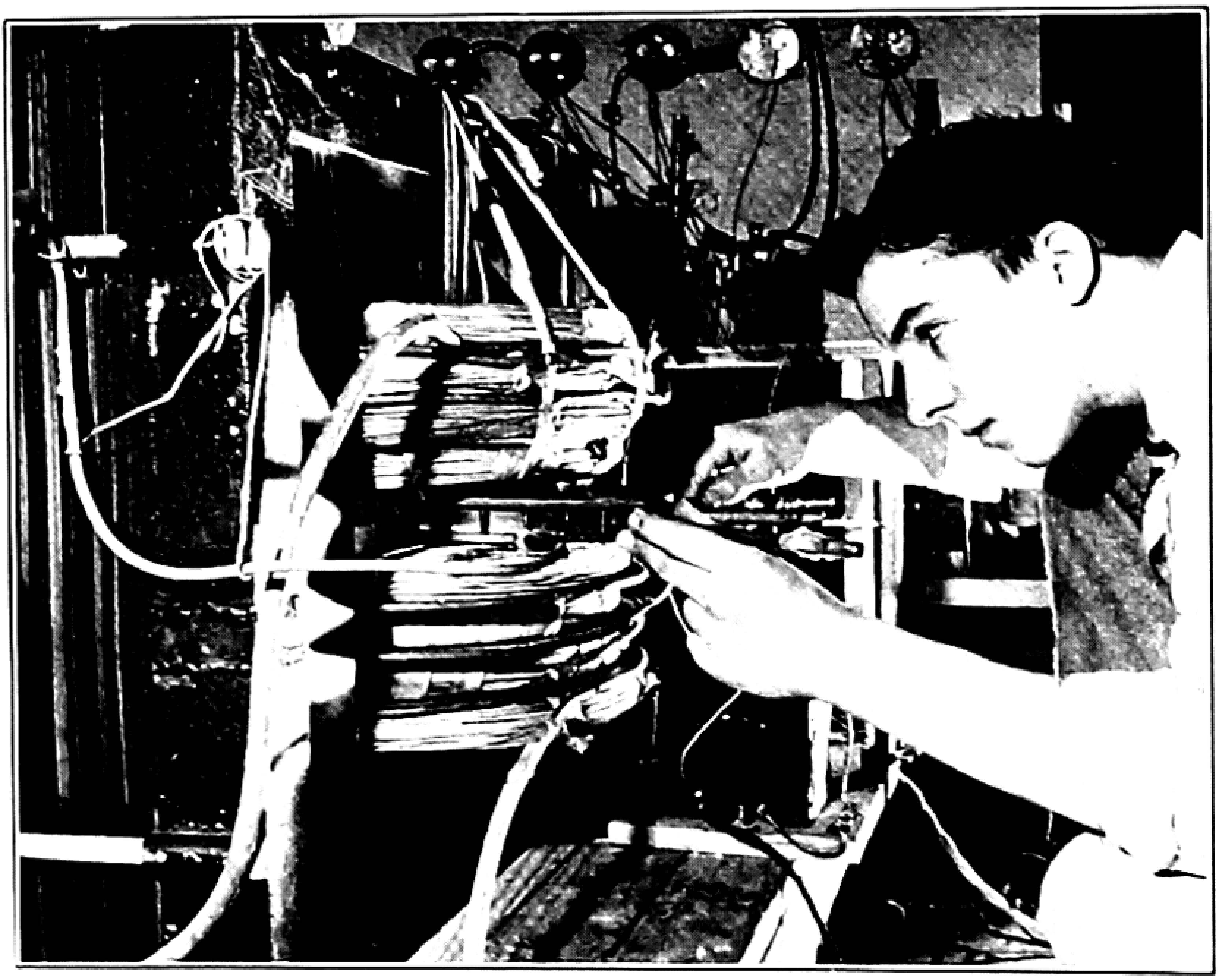

FIG. 20. A Westinghouse Talent Search winner places a vacuum chamber containing material to be made radioactive between the two copper coils of an "atom-smasher" he built himself. This half-million electron volt cyclotron contains some 3,000 pieces of steel in its 800-pound rectangular magnet. Cloth straps prevent the front of the top coil from sagging. (*Photograph courtesy of the Westinghouse Electric & Manufacturing Company.*)

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[1] Meister, Morris, "Science Education Looks to Industry," *Report of Proceedings, Regional Conference on Industry-Science Teaching Relations,* National Science Teachers Association, Washington 6, D.C., 1949.

dents involved, together with parents, families, and American communities.[5]

Basic Concepts

Correlation of physics with life is a phase of instruction most important in terms of the integrating education of high school students, hence this factor will be stressed in our consideration of approach and emphasis within the present chapter. The rise of biophysics parallels that of biochemistry in modern science, advances and contributions pyramiding in research at the university graduate school level and in post-doctoral study. Basic concepts of *energy* transformation and conservation, including atomic energy in peace and in war, *matter* itself, and a foundational consideration of the *physical nature of life* will add breadth and depth to secondary school physics. Integration of these facets, furthermore, will convey to high school students a sense of the kinship of all science, which might otherwise be delayed until the university upper division for the professionally minded students and missed altogether by those enrolled in an industrial-training or community-life preparatory terminal program.

The majority of students electing a senior course in general physics do so in preparation for college or university work of prescribed nature in terms of entrance requirements laid down as prerequisite in science and mathematics, hence will not absorb the significance of a sound biophysical foundation unless specific attention is given to it. In order to complete our progressive overview of secondary science education in terms of the "whole individual," means of integration and correlation may be indicated at this point.

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[5] Trytten, M. H., "The New Science Foundation," *Scientific American,* Vol. 183, No. 1, July, 1950.

Electronics [6]

Each of the varied substances known to man may be classed as "living" or "nonliving." Students of high school physics realize that the universe of which our planet is a part is composed of matter, made up of molecules or groups of atoms. The teacher will point out that each atom is composed of electrons, which carry negative electrical charges, and protons, which are positive. A group of atoms in solution which bears an electrical charge or reacts as a unit we know to be an "ion." There are "cations," which carry an excess of positive electricity, and "anions," which bear an excess of negative electricity.

There is wide opportunity for laboratory experimental work, group study, and application of basic principles inherent in the preceding paragraph detailing type content. Electronics,[7] involving a-c, d-c circuit construction, connections, arrangement on assembly panels, and even art integration in preparing the finished products for classroom use, offers excellent correlative fields. Derivation of much useful classroom equipment for demonstration and group practice work is of practical benefit to both students and instructor.

One of the author's most useful pieces of teaching equipment is a colored state relief map, size 3 by 5 feet, constructed on a movable wooden base and inclined rear support. This instrument, wired so as to flash green lights when correct contacts are made and red when errors in point contact are committed, is used in emphasizing state bridges, highways, railroads, airports, power sources at giant dams, transmission lines, chemical and physical research centers, and similar topics. Transportation of pure mountain drink-

[6] Teachable topics of current interest will be found in *Electronics*, a magazine devoted exclusively to this branch of physics. The address will be found in Part II: Resource Aids, Magazines Useful in Secondary Science Education.

[7] See Stollberg, Robert, "Suggestions for Teaching Electronics," *The Science Teacher*, Vol. XVII, No. 1, February, 1950, and No. 2, April, 1950.

ing water from source to consumer, national parks and monuments, endemic tree groups, altitude and latitude factors, as well as many other subjects of correlative biological nature, are made clear in this way, integrating social science and life science in general education.

Another setup embodies a series of wooden compartments in which bird mounts, insects, minerals, or metal specimens may be placed as desired. It has an identification panel down one side using key card labels (which may be changed as needed) for ornithological, entomological, mineralogical or metallurgical identifications in the classroom. Correct placing of insert plugs illuminates the compartment, while the compartment remains dark in the case of incorrect identification and wrong electrical contact. The construction of such devices as these brings study, research, and manual skills into play, with desirable results of many kinds in secondary education.

ENERGY

Through teacher presentations, socializing discussions, and laboratory work on electronics, foundations may be laid for the physics major unit of work on energy. The fact will be brought out that opposites attract while similarities repel, a basic rule of electrophysics. Since this repelling and attracting process is continually in operation in all nature, changes constantly occur, as evidenced by such demonstrable phenomena as heat, light, erosion, and chemical reactions, all forms of active or "kinetic" energy.

Energy may be held back or imprisoned, but it is continually capable of producing activity. Forces thus held apart tend to flow together and will do so at the first opportunity. This withheld force, possessing the power or ability to perform work, in the sense that the term "work" is used in physics, is known as "potential" energy. An ax raised in mid-air, a storage battery, a coiled spring, and a bent bow are examples of potential energy. Potential we know to be the energy of position or of power, while kinetic is that of motion.

Another consideration applicable in our type survey is that potential energy may be transferred into kinetic, and vice versa. A young man in the high school gymnasium who raises his arm to the vertical position and then swings it through an arc forward or backward until it reaches the vertical again, illustrates this point. When the athlete's arm is extended in vertical position, energy is potential, that is, present but not yet expended. As his arm swings through the arc downward the potential energy is transformed into kinetic or forceful energy, reaching its greatest expendable power as the arm pendulum reaches the center of oscillation. As the arm swings back again to the vertical position the reverse takes place and work is done, kinetic energy being stored as the upward motion slackens, being transformed into potential again.

Biological Correlation

To teachers-in-training it may seem a far cry indeed from such a type presentation to the conservation of a normal school-community environment and the physical, mental, and economic well-being of living organisms, yet many such transformations take place continuously in nature, as all science educators realize. In our own bodies and in those of lower animals, as well as within the bodies of plants, whenever the active chemical element oxygen combines with something else (oxidation), heat is produced, which is as true in the body of the cat before the fire as it is in the fire itself. The rusting of a small nail in a corner of a city junk yard, for example, produces measurable heat.

As a matter of fact, potential energy in the bodies of certain animals (invertebrate and vertebrate) actually converts heat resulting from oxidation into radiant energy in the form of phosphorescent light. Marine organisms such as *Noctiluca,* the coelenterate sea pansy *Renilla,* and many deep-sea fishes, such as the luminescent angler *Lasiognathus,* illustrate this point.[8] The two fundamental considerations (matter and energy) thus developed in our exemplary portion of a presentation in twelfth-grade physics are of integrating significance in bringing about comprehension of some factors involved in the ecological interrelationships of all living things.

Thoughtful students of senior grade will raise two questions in your class: Where does this energy found in matter originate? and What becomes of it? Food in its varied forms may be reduced to animal and vegetable classification. Animals themselves, in fact, may be grouped into carnivorous, herbivorous, and omnivorous types, upon a dietetic basis. Carnivorous animals eat meat; herbivorous animals eat plants; omnivorous animals eat both plant and animal food.

It is well known that those animals which feed almost exclusively upon meat, such as lions, tigers, and leopards, in effect are eating plants also, for they eat animals which eat plants, or they eat animals which eat animals which eat plants. So the quest for the source of food energy eventually takes physics students into the botanical world. The all-important process known as "photosynthesis," which has been studied previously during the science outgrowth process, makes use of two compounds, water from the ground and carbon dioxide from the air, to make food in green plant leaves and stems. Many kinds of animals, including humans, make use of this plant food material by eating the green plant or some portion of it. Some plants as well as animals are "parasitic," obtaining their nourishment from other living things, or "saprophytic," being dependent upon dead tissue for food. Dodder (*Cuscuta*) is a true plant parasite; any mushroom, such as *Agaricus,* is a saprophyte.

An important phase of the food-manufacturing process has yet to be brought out and will develop through student discussions, namely, that *light* is essential to its completion.

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[8] Wells, Harrington, *Fish and Fishing,* pp. 68–74, Harr Wagner Publishing Company, San Francisco, 1946.

Water and carbon dioxide will not unite in the absence of chlorophyll-treated light in living cells, the ultimate natural source of which is our sun, but one of billions of "stars" in the colossal infinite, stretching a billion light years into space, which we term the "universe."

Radiant energy streams from our sun toward the earthly plant leaf, where it is converted through plant chemistry into potential force as carbohydrate food. The rate of heat energy reaching the plant surface averages about one kilocalorie per minute for every square foot of area. Both heat and light are absorbed, the chlorophyll absorbing green, red, and blue light both in the case of land plants and in fresh- or salt-water aquatic algae. Decay, time, and the varying pressure of geologic strata upon dead plant bodies form peat and bituminous and anthracite coal, which actually represents the radiant energy of our sun imprisoned as potential energy, released as heat when oxidized or "burned." In summary, these principles should be presented to the physics class, for in last analysis all living things depend upon photosynthetic plants for food energy, our *sun* being the ultimate source of energy on this planet.

Energy Conservation

In answer to the second question, regarding the fate of energy, physics teachers will point to a cornerstone of their science, the principle of energy conservation. Throughout the changes from potential to kinetic, muscular, electrical, chemical, or radiant energy the law holds good: although earthly energy may be varied in form, it is neither created nor destroyed. Whenever energy is put forth in a machine, it results in work done and in heat or light produced. In the case of work done (elements separated, bow bent, weight lifted), energy is stored as potential or released as kinetic. In the case of heat produced (friction), radiant energy results. Energy is thus never lost but simply changed in form.

Significant work has been done in university biophysical laboratories investigating the effects of energy radiation and the factors of light antagonism.[9] Such far-reaching experiments may well be called to the attention of younger students as examples of the interdependence of physical and life science.[10]

Atomic Energy

In peace as well as in wartime, atomic energy occupies perhaps the most prominent position in the modern integrated course of study in secondary school physics.[11] The discovery of *neutrons* in 1932, tiny particles of matter without electrical charges which possess the power of by-passing electrons to bombard the nucleus of an atom, radically changed the basic concepts of physics teaching. Radioactivity of chemical elements and the actual splitting of the atom, announced in 1939, paved the way for a complete reorganization of instructional emphasis.[12] Energy and mass were proved to be interchangeable.

Classroom presentations and group investigations center about two integrating topics, (*a*) the peacetime long-range theoretical and applied uses of nuclear energy and (*b*) the omnipresent possibility of atomic-bomb attack during wartime. In both these life situations, students of secondary school physics may be expected to take the lead in interpreting principles of applied physics to members of the local community at large, including the family circle within the home. From a sociological viewpoint, this may indeed be an important function of secondary school physics teaching, since most people do not understand nuclear physics as expressed in the term "atomic energy" so often read in the daily newspaper and heard on the radio. A reading source table in the classroom laboratory may be kept supplied with informative pamphlets for free distribution among and by your students.[13]

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[9] Wells, Patrick H., "The Influence of Visible Light on Recovery of Cells from Ultra-violet Radiation Injury," *Turtox News,* Vol. XXVIII, No. 7, July, 1950.

[10] Wells, Patrick H., and Giese, Arthur C., "Photoreactivation in Gametes of the Sea Urchin *Strongylocentrotus purpuratus,*" *Biological Bulletin,* Vol. 99, No. 2, October, 1950.

[11] Light, Israel, "Atomic Energy and the Social Studies," *Social Education,* Vol. XIV, No. 2, February, 1950.

[12] Born, Max, "Physics," *Scientific American,* Vol. 183, No. 3, September, 1950.

Teachers-in-service, as well as teachers-in-training, desiring up-to-date information and supplementary material will find large sections of modern textbooks devoted to the subject of nuclear fission, and many reference texts offer varied degrees of complexity in treatment from which stimulative content may be derived as indicated.[14]

Peacetime uses for atomic energy presented in the physics classroom include the production of "isotopes," employed in chemical research as well as in medicine. These products of fission, perhaps intensively studied for the first time in the senior physics class, are used in many ways, including the tracing of chemical reactions and as a substitute for X rays in making photographic studies of metallic structures.

Another peacetime derivative of atomic-energy production is *heat*. One pound of uranium 235 is theoretically equivalent to a thirty-car trainload of coal; hence, in terms of energy content, it is infinitely cheaper than coal, even if the locating and producing costs with relation to very low-grade uranium should enormously multiply beyond current levels. Physical scientists are at work on the problems involved in harnessing the terrific temperature developed as nuclear reactors form plutonium from natural uranium. In theory, it is possible to conduct such heat to a remote group of buildings or even to neighboring towns from a central production unit, provided that metals are developed for such use which can withstand the temperatures involved. Experiments toward this end have been carried on in England and America, generated heat being turned into electrical energy, the latter being converted to radiant form at the desired outlets.

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[13] For example, Chubb, L. W., *The World within the Atom*, Westinghouse Little Science Series, Pittsburgh, 1946.

[14] See the Subject Bibliography on Physics in Part II, Resource Aids.

A third peacetime derivative is *power*. Submarine and other ship propulsion units are actually under construction, and even airplane engines designed for nuclear power are being built, following the completion of preliminary studies under the NEPA (Nuclear Energy for Propulsion of Aircraft). Eventually it is possible that small power units suitable for automobiles may be produced, in spite of the difficulties attending provision for adequate protection against radiation. As physicists learn more about uranium and thorium, developing techniques of mastery and utilization, these and similar problems will be surmounted as have innumerable obstacles which have blocked the progress of science in the past.

Of many topics suited for socializing discussion which arise relative to control of atomic energy, the problem of degree of governmental participation in and subsidization of experimental establishments (which are tremendously expensive) is vital, in the interest of general public welfare. Many more stations are needed in addition to those at Hanford, Washington; Long Island, New York; Oak Ridge, Tennessee; Paducah, Kentucky; Los Alamos, New Mexico; and near Chicago. As physicists develop new techniques of isotope creation and utilization, power production, and control of heat transmission, and as mineralogists uncover fresh sources of uranium ore world industry will move into a new and miraculous atomic age. All peacetime developmental activities, however, no matter how desirable they may be from a sociological standpoint, must await return of world conditions to such form as will permit of scientific applications for the betterment of man.

Wartime developmental use of principles involved, including gamma-ray and heat-flash radiation, is the second fundamental field of atomic-energy application. Youths currently in the physics classroom will move immediately into the armed services, there to remain for approximately two years of military training. Many who are today enrolled in senior physics will one day specialize in the modern fields of atomic-weapon development and ordnance research, hence motivation and effect psychology are no longer teaching problems. The newest weapons of modern warfare, atomic artillery shells, were tested and proved sensationally successful early in 1951, near Las Vegas, Nevada. Their use may make infantry concentrations and massed tank movements fatal to an enemy.

The long-range effects of atomic explosion are still being studied by scientific investigators at Bikini. The Atomic Energy Commission has supervised study of biological and physical changes since the Baker Day test of July 25, 1946, much valuable information having been accumulated with relation to the concentration within living tissues of aquatic animals, of radioactive isotopes formed in the single atomic act of that date. The remote and residual effects of atomic explosion, which are reported to be still present,[15] indicate the extent of wartime injury possible long years after atomic warfare.

The importance attached to nuclear fission during the period of America's preparation for war may be grasped when the class realizes the magnitude of our defense spending outlay in a single year. The Atomic Energy Commission administered a $260,000,000 appropriation for military nuclear reactors during 1950, foundations being laid for tremendous expansion in this field of physical science. Among projects sponsored of particular interest to the physics class is the $9,000,000 "bevatron" constructed in a 2-acre circular building on the Berkeley campus of the University of California. More than 10,000 tons of steel and 140,000 feet of 2-inch copper cable have gone into the great ring-shaped magnet forming the atom-smashing bevatron, which produces a beam of atomic bullets with an energy of 6 billion electron volts!

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[15] Hines, Neal O., "Bikini Report," *The Scientific Monthly*, Vol. LXXII, No. 2, February, 1951.

Even the vastly improved atomic bomb now possessed by the armed forces is superseded by the hydrogen bomb, derived from the utilization of small amounts of tritium, an artificially produced heavy hydrogen isotope, employed with deuterium atoms to produce the most lethal weapon in the history of the world. It will be well to stress, in connection with atomic research, that all Americans alive today may owe their future existence and that of their children to the genius and productivity of nuclear physicists.

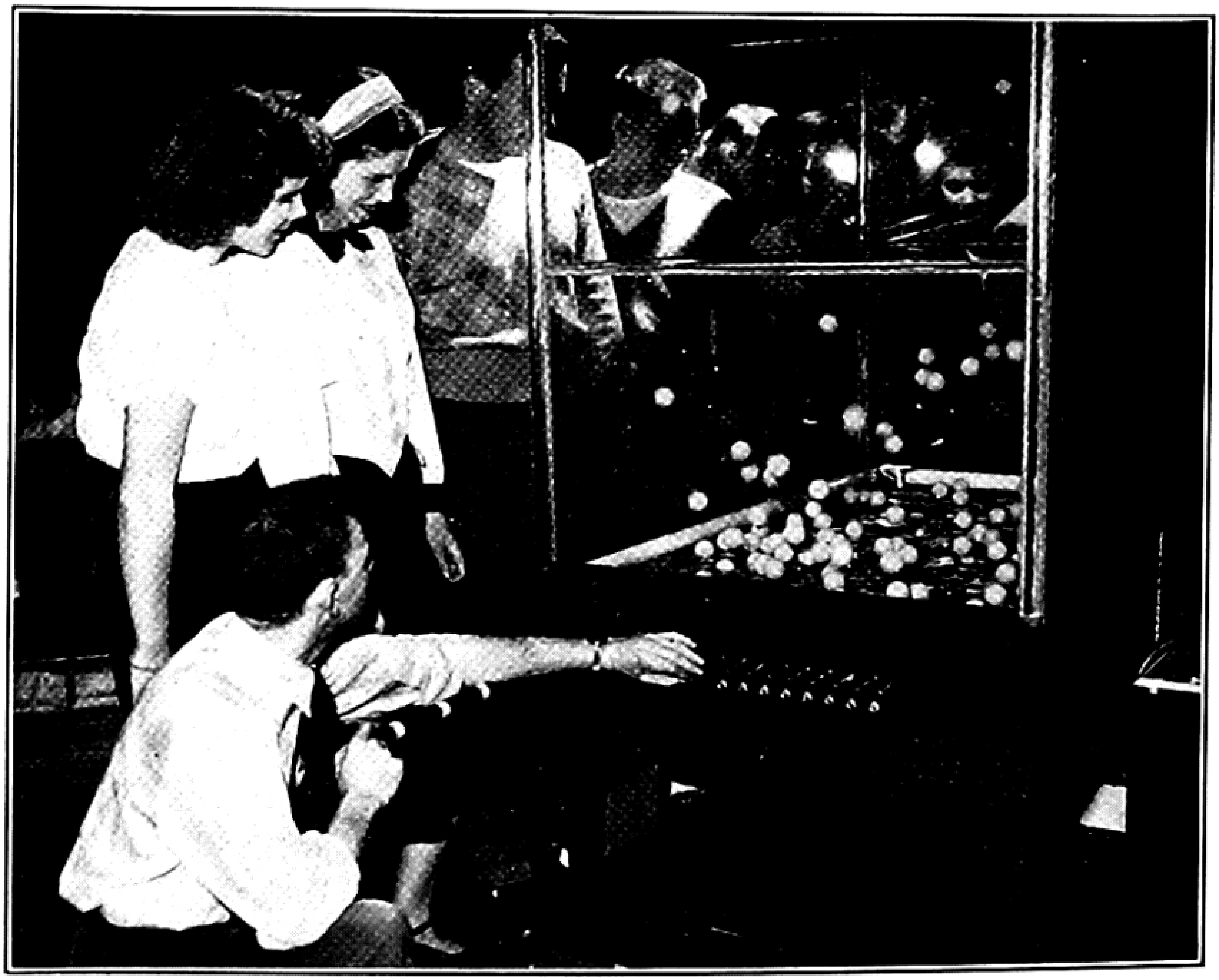

FIG. 21. The "ping-pong power pile" chain reaction, demonstrated before a group of high school science students on a "field-trip" visit to an industrial exhibit. The lightweight balls simulate an actual uranium pile reaction made possible by nuclear fission. (*Photograph courtesy of the Monsanto Chemical Company.*)

With regard to steps being taken toward the education of citizens in defense against atomic warfare, it is evident that the high school instructor in physics must play a very important role indeed.[16] Senior boys and young women who will shortly enter the armed services, as well as those young people who will stay at home, must be skillfully and thoroughly taught the principles of nuclear physics as a foundation for intelligent comprehension of radiation and its terrible effects, as well as for means of protection against them. Those members of the local community who attended high school in a less socially dangerous era naturally did not receive any such instruction, even if they were enrolled in physics. It is obvious that the physics teacher, especially in an urban secondary system, has a double-barreled responsibility in making the facts known, not only to his pupils but to their parents at home as well.

Protection against atomic blast is a primary precaution, maintenance of a bomb shelter being the best defense. If none is available, teach your students to find any shelter quickly, such as in a corridor in the school basement or under a desk in any schoolroom, away from the windows, facing the wall. If they are unable to reach the building or a thick wall, students upon glimpsing a great light in the sky must be taught to throw themselves instantly upon the ground, closing their eyes and remaining face downward for at least two minutes.

Training for survival following a bomb blast involves instruction in reasons why your students must wash thoroughly with soap and water or, if no water is available because of the blast, rub their bodies with paper towels taken from lavatory dispensing containers, thus reducing the extent of radioactive contamination. Students must be taught that most ordinary foods and water sources would be subject to the effects of radiation and would probably be unsafe. Bottled beverages such as soft drinks, bottled water, or water contained in glass containers within closed refrigerators would be safe to drink. Food or water in cans of all types could be consumed with safety.[17]

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[16] Gillette, B. Frank, "Nuclear Energy in High School Physics Courses," *Science Education*, Vol. 34, No. 1, February, 1950.

A feature of the class in modern physics should be demonstration and practice in the use of Geiger counters in the laboratory as well as in the field, for the time may indeed come when such an instrument (itself a demonstration of applied research in physics) will be almost as familiar in our homes and in our daily lives as the vacuum cleaner is today.[18] Such content typifies the present classroom of modern integrated physics—practical, realistic, and up to date, in preparation for life tomorrow.

MATTER

Matter assumes one of three forms, being either solid, liquid, or gas. Your students will learn from the study of physics that molecules are continually in motion, even in solids. The speed of such molecular movement is apparently regulated by molecular attraction, variation in the cohesive or attracting power of molecules for each other therefore producing variations in substance. If the cohesive tendency is great, molecules cling together, producing what is called a "solid." If a slightly lesser degree of attraction exists, a flowing motion is permitted (varying with the type of molecular attraction or the molecules concerned), which results in a "liquid." If there is little molecular attraction, molecules tend to fly apart or diffuse at each opportunity, this widely separated condition lessening their mutual attractiveness. Molecules thus widely separated constitute a "gas." It is a demonstrable fact that matter is interchangeable in these three forms, which makes an interesting lesson in physics. Solids may be melted to become liquids, evaporated as gases, condensed to become liquids again, and frozen as solids.

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[17] Detailed discussion will be found in the Federal bulletin, *Survival under Atomic Attack*, prepared by the National Security Resources Board, obtainable from the Superintendent of Documents, Washington 25, D.C.

[18] Lauritsen, C. C., and Lauritsen, T., "A Radiation Meter for Disaster Use," *Science*, Vol. 112, No. 2901, Aug. 4, 1950.

Some students will observe that occasional substances are difficult to classify. Iron, when heated, may be molded, as may silver and gold. Lead is not a true solid, heavy though it may be. Layers of lead and gold placed and held close together will fuse, particles of one being found in the other after a time. Pitch may break into pieces in the hands, yet when rolled into a ball in the laboratory, it flattens out and flows like a liquid. Crude oil, molasses, and mercury are examples of liquids which border on the solid state, owing to the relatively strong cohesive power of their respective molecules. If a little mercury is spilled upon the physics

FIG. 22. An industry-sponsored demonstration before high school students of physical property changes at transformation temperature. (*Photograph courtesy of the United States Steel Corporation.*)

demonstration table, for example, many little droplets are noticed. The smaller of these droplets are almost spherical, due to the surface tension set up by the mutual affinity of molecules. Even in the case of water, an exceedingly free-flowing liquid, molecular tension may readily be demonstrated in the laboratory by floating a paper clip on its quiet surface.

Physics students quickly learn that gases or solids may be mixed with liquids, gases with gases, or liquids with liquids. As has been indicated in our survey of chemical content, in the case of solid matter mixing with liquid matter, three possibilities exist. The mixture may be complete so that the solid dissolves in the liquid solvent. Such a mixture in which the component parts are indistinguishable is said to be a "solution." On the other hand, if the solid particles of matter remain undissolved and distinguishable in the liquid, the resulting heterogeneous matter is termed a "suspension." As a third alternative, the instructor may show that the two may mix "under protest," so to speak, forming a suspended solution called an "emulsion." Mayonnaise is an emulsion, as is milk.

THE PHYSICAL NATURE OF LIFE

Protoplasm itself may be introduced into the physics course, just as it is into eleventh-grade chemistry. In the mass, the life substance is composed largely of water, with about 15 per cent protein and smaller amounts of fats, carbohydrates, and other compounds. Physically, however, protoplasm deviates in some respects from the laws of the science which govern the behavior of liquids. Newton's law, which states that liquids are free of inner elasticity, and Stokes' law governing the path of particles through liquids, are examples.

The instructor will emphasize the fact that living matter may also assume physical characteristics similar to a thickened jelly. When protoplasm is observed to be in this apparently solid physical state, it is described as a "gel," and when it appears to be liquid, as a "sol." Temperature, pressure, availability of water, food materials, and oxygen, as well as other factors, affect the physical condition of plant and animal life substance, hence students will see that the viscosity and other properties of living matter vary considerably under differing environmental conditions.

Physical Theories[19]

The microscopic appearance of protoplasm also changes from time to time, the physical structure being variously described as "alveolar," "granular," and "reticular." According to the *alveolar* theory, the life substance is an emulsion, consisting of globular spheres overlapping one another. The *granular* theory represents protoplasm as being composed of tiny dots, or grains, floating in a watery liquid field as seen under the microscope. (It will be well, after discussing these views, to have your students go to the board and diagram their conceptions of them. Simultaneous recapitulation of mixture, solution, and emulsion definitions will be indicated).

Those investigators in biophysics who advance the *reticular* theory state that life substance is a network of fibers which are interwoven with each other, the interstices being occupied by water, salts, lipids, and other cell constituents. The modern version of the reticular theory, which seems quite tenable, proposes that the long protein molecules themselves form the reticulum, being attached by various reversible chemical bonds at points of contact. Of course, protein molecules as structural units are submicroscopic in width, hence it should be emphasized that students cannot expect actually to see the reticular structure of protoplasm through their microscopes in the physics laboratory. Globules and granules (which must be considered as being superimposed upon this basic structure) are, however, often microscopically visible.

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[19] For a complete presentation in technical terminology, see Frey-Wyssling, A., *Submicroscopic Morphology of Protoplasm and Its Derivatives,* Elsevier Publishing Company, New York, 1948.

Let your classroom recapitulation of the physical nature of protoplasm include the observation that protoplasm is a variable substance, exhibiting changes in molecular composition and organization, and that physicists now know considerable about it. The chemical composition of the life substance is known, including the elements concerned and how much there is of each. Understanding the physical nature of life, physicists should be able to create life in the laboratory, and theoretically it is quite possible to create a Frankenstein which would materialize out of an Erlenmeyer flask! Yet no biophysicist or physical biologist at any university, nor any research worker anywhere in the world, no matter how renowned in science, has produced synthetic protoplasm.

Investigation

Choice of topics for individual and group research must be entirely selective, self-formative, and voluntary, for each student should at this stage of his maturation in the processes of the scientific method be quite capable of working out his own postulations and procedures. All phases, including historical perspective, approach, experimental accumulation of data, organizing facts, and formulating conclusions, should be worked out in advance and carried through in culmination of the year's study.[20] If optimum results are to be obtained, this research leadership must not be required of all students, for a blanket assignment of this nature will defeat its own purpose. Rather, the way may be opened, the instructor standing ready to assist or to aid in recruiting assistants from classmates and to advise, during class or after class, through indication of limitations, interpretation of difficult portions of higher physics or mathematics, and understanding stimulation.

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[20] Refer to discussions in Chap. 2, Science and the Scientific Method.

Culmination

When the results of such independent study have become apparent in term-paper or thesis form, committees, groups, and individuals will be encouraged to present their findings before the class as a whole, either during school periods or in special meetings held after school or during the evening, perhaps at a series of "science club" meetings.[21] If the evening plan is decided upon, friends and parents may be invited. Young scientists thus receiving direct encouragement in their embryonic efforts at achievement and recognition will culminate their physics learning and, in fact, the entire period of elementary and secondary science education on a high intellectual plane.

Rapport

Utilizing the methods and respecting the past achievements of science, students will be led forward toward happy, fruitful lives as key experiences are provided and shared. There is more than empirical, ecological interaction between human organisms and environment involved; there is a spirit of morale in investigation earned and learned through watching, listening, and participating, which combines humanitarian idealism and scientific pragmatism with the principle of effect—a difficult combination to excel in education at any grade level. When all this is brought about in a spirit of friendliness and encouragement, results are doubly effective and impressions are retained for life.

The science teacher need not be an inverted automaton—a stolid, bored, unresponsive, socially inept character, to be ignored if not disliked by the multiple personalities with whom he comes into contact. He need not be a stern disciplinarian who enforces attention and feigned interest during lesson periods. He need not suffer the embarrassment of seeing student groups dissolve upon his approach, or happy conversation die out as he walks by on the campus path. He may, if his professional training has directed conscious attention to such factors, become a respected leader of young people, a wise and stimulative friend, a confidant, a teacher in whose classroom one may "hear a pin drop" when he makes a presentation or performs a demonstration.

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[21] Mallinson, George Greisen, "Sponsoring the Science Club," *Faculty Contributions*, Graduate Division of the Western Michigan College of Education, Series II, No. 1, April, 1950, Kalamazoo, Mich.

Anyone properly schooled in physical science may set up experiments, draw out problems, deliver lectures, balance equations, draw diagrams, criticize reports, administer examinations, and in all standard ways go through the motions of orthodox pedagogy. Too many uninspired science teachers are tottering toward retirement in frustration and in secret bewilderment today, encysted in sarcasm and encrusted with dogma, when a partial shift of emphasis from cold physical subject matter to warm human interpretation is the simple key which would unlock a treasure chest of achievement and respect. At the critical summation period of secondary science, educational power and intellectual vigor must be generated in young minds, curiosity must be inculcated as a mode of life in embryonic scientists, and appreciation as well as comprehension must be teamed with constructively critical evaluation and open-mindedness. Above all, *character* must be glorified through encouragement and precept; for without character, no young man or young woman will succeed in later life.

Reverence

As a final phase in our survey of what is basically good in physical science teaching at the secondary school level (or anywhere else), there remains for consideration a criterion which stems from all the others. It will be fostered among maturing students in direct proportion to teacher-class rapport, practical and modern course content, development of the scientific method, historical perspective, and social intercorrelation. This is the presence of a humble, yet pulsing, vibrant spirit of reverence in investigation and with relation to the profession of education itself. You will need to possess this quality in order to impart it to others, and it will be a source of inspiration to your students to know that scientists and educators stand before God and his revelation in such a spirit.[22]

The reverent and humble educator realizes the significance of underlying sociological and psychological factors which temper and influence the attitudes of adolescents toward school, toward their parents, toward a world of international rivalry and tension, toward morals, and toward life itself. Bertrand Russell [23] long ago defined this realization upon the part of successful teachers in terms of *reverence* toward the mind and body of each individual who enters the educator's sphere of influence, in or out of the schoolroom. This spirit of humility in the presence of science and reverence in terms of scientific revelation and human personalities goes beyond the confines of the laboratory when it attains expression through exemplary leadership in character development. It reaches toward the infinite mysticism in philosophy when it assumes control over a lifetime spent in helping others, laying stress upon insight into human problems and continual progress toward human betterment.

Reverence toward students, toward one's subject field, and toward a career of striving for fact and law is a quality found without exception in the graduate university science laboratory, for here we have in the persons of our directors and those intimately associated with them a union of idealism in devotion to science as pure science; a tireless, comparatively unremunerative devotion to search for essential fact without reference to economic importance or worldly gain. In the idealistic sense, in terms of the privileged few who live and labor in such a refined atmosphere, these university scientists are among the greatest educators, for they exemplify the spirit of research through lives spent in humility and reverence toward mankind and toward God's natural truths.

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[22] Wells, Harrington, "Science and Religion in Education," *Science Education*, Vol. XXVI, No. 2, February, 1942.

[23] Russell, Bertrand, *Why Men Fight*, Appleton-Century-Crofts, Inc., New York, 1917.

The teacher of science in the secondary school will have little direct opportunity for pure science as he busily engages himself with the world of reality encompassed by the four walls of his classroom laboratory. In a larger idealistic sense, however, he has the advantages of multiplied contacts in daily life; a younger and more pliable student clientele; and far greater opportunity for direct application, social experiment, and stimulation of collective intellectual power through individual precept. To combine leadership in scholarship and social orientation with a human realization of the subconscious strains which beset the minds and bodies of young people in the secondary school laboratory is to take the final important step in professional preparation for science education.

COURSE OUTLINE FOR PHYSICS

Unit I. "Introduction to Physics."
  The history of physics.
    Ancient problems of the Egyptians, the Aztecs, and the Incas.
      Temple and pyramid construction.
    Greek philosophers and their physical concepts.
      Archimedes, Thales, and Ptolemy.
    Renaissance physicists and their thought.
      Copernicus, Galilei, Volta, Galvani, Ohm, Newton.
    Applied physics of the early modern period.
      Contributions of Edison, Bell, Westinghouse, and Morse.
    Modern physicists and their work.
      Einstein, Lawrence, Millikan, and contemporaries.

Unit II. "Biophysics."
  Matter and energy in nature.
  Potential and kinetic energy.
  Physical characteristics of protoplasm.
  Environment as a set of physical factors influencing life.

Altitude, depth, latitude, temperature, humidity, wind movement.

Unit III. "Molecular Physics."[24]
- Solids, liquids, gases.
- Diffusion.
- Elasticity.
- Capillarity.
- Surface tension.
- Solutions, suspensions, emulsions.

Unit IV. "Work."
- The pulley.
- The lever.
- The fulcrum.
- The inclined plane.
- The screw.
- The wheel.

Unit V. "Force and Motion."
- Power creation for use of man.
- Power transmission.
- Speed.
- Mass.
- Inertia.

Unit VI. "Heat."
- Fahrenheit and centigrade temperature measurements.
- Expansion and contraction.
- Radiation and convection.
- Reflection.
- Freezing, boiling, melting.
- Evaporation and condensation.

Unit VII. "Magnetism and Electricity."
- Electric currents (a-c and d-c).
- Electromagnetic induction.
- Generators and transformers.

[24] For exemplary demonstrations, laboratory experiences, and projects, see Richardson, John S., and Cahoon, G. P., *Methods and Materials for Teaching General and Physical Science*, pp. 264–417, McGraw-Hill Book Company, Inc., New York, 1951.

- Electrolysis.
- Electronics.
  - Modern magnetic and nonmagnetic electron microscopes.

Unit VIII. "Sound."
- Wave motion.
- Telegraph transmission.
- Telephone.
- Radio.
- Radar.

Unit IX. "Aerodynamics."
- Atmospheric pressure.
- The principles of meteorology.
- Comparative aerodynamic designs such as pressurized cabins.
- Parachute design and materials.
- Cylinder propulsion.
  - Water- and air-cooling systems.
- Jet propulsion.
- Rocket propulsion.
- Problems of supersonic speed.

Unit X. "Light."
- Mirror reflection.
- Refraction and dispersion.
- Color and color dynamics.
- Principles of camera photography.
- Motion pictures and slidefilms.
- Television and color television.
- Radiation.
  - X rays.
  - Ultraviolet rays.
  - Infrared rays.
  - Cosmic rays.
  - Neutrons and atomic energy.
  - Isotopes and nuclear fission.
  - The challenge of nuclear physics.

Culminating Individual and Group Investigation Reports.

PROBLEMS FOR GROUP DISCUSSION AND REVIEW

1. Compare high school chemistry and physics teaching as culminating fields of secondary science education.
2. What differences in student personnel would you expect to notice between the ninth-grade course in general science or general biology and the course in senior physics? How do you explain the differences noted?
3. In what ways would you emphasize the over-all significance of energy sources, transformation, and conservation?
4. Discuss the process of photosynthesis from a chemicophysical viewpoint. Why discuss it at all in the physics classroom?
5. Explain what is meant by "light antagonism." Can you visualize possibilities in this field of interest to high school students?
6. What are the three basic products of nuclear fission? Explain the theoretical and practical peacetime uses of each product.
7. What should you teach your students to do in case of an atomic explosion? How will you reach the students' parents?
8. Discuss means of presentation of the physical nature of protoplasm.
9. Do you believe religious reverence has a place in scientific research? State your reasons for believing the way you do.
10. In what ways and to what extent may the secondary school physical science teacher influence the personal character of his students? Do you believe that science teachers should have a definite part in character education, along with the "gym" teacher, the coach, the boys' counselor, and the dean of girls? Defend your viewpoint.

Chapter 10. EVALUATION AND DIAGNOSIS

More than mere discussion of methods of presentation in terms of measurement is involved in the evaluation and diagnosis of results of secondary school science education. In up-to-date professionally supervised programs today the stress is upon *interpretation* of student behavior in terms of desirable objectives. Such emphasis delves deeper into cause and effect than any formal testing program, however valid in subject-mastery record. To a much lesser degree, of course, the situation is analogous to the "Graduate Record Examination" currently in vogue with respect to students (including teachers-in-training) who propose to enter upon graduate study at many of our universities. Profiles and aptitudes are to be considered, along with intangible attitudes and tangible subject-mastery criteria.

Our best science supervisors today, as well as the teachers to whom they point with pride, are able and anxious to collaborate with the division of student guidance in attaining a true picture here as elsewhere. A cardinal principle of educational psychology is nationally accepted: the consideration of the whole pupil personality with relation to his or her place in the world of the present and future. Behavior in natural, as well as artificial, situations then becomes a matter of interest if we are to set up means of evaluating genuine assimilation. It is no longer enough to give several examinations during a term and grade accordingly. We must learn to watch students as individuals so as fully to measure absorption.[1]

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[1] *The Measurement of Understanding,* Forty-fifth Yearbook of the National Society for the Study of Education, Part I, University of Chicago Press, Chicago, 1946.

We, as science educators, must now evaluate our own work; we must know our own minds. We should be able as faculty groups to agree upon end-product objectives. In our own thinking, as well as in our professional administration of the testing program, there will be two major aims involved: (1) clear definitions of outcomes desired in terms of functionally effective life in a democratic society, and (2) selection of efficient, applicable evaluation aids.

Diagnostic Factors

Observation, comprehension, and to a degree manipulation of student behavior become matters of relative importance in judgment, for there are other factors than grades bearing upon diagnosis. Parrotlike answers to teacher questions, glib recitations from memory, and formal written examinations are not absent from the secondary science program in practice; it would be simple foolishness for an experienced educator to pretend that such is the fact, or that it would even be desirable to banish them. But over and above these there are superimposed factors which in themselves may affect mastery. Psychological reaction is one of these, for young people develop phobias and complexes which may become fixations unless countermeasures are taken. How many times, for example, have college instructors listened to such statements as "I never was any good in science," "I guess science is just not my subject," or "I'm sorry, professor, but I just hate science. I just can't stand wriggling, crawling things. Once I had to cut into the head of a living frog and destroy a part of its brain. Then I had to watch it and tell what happened. I can still hear the 'crunch' as my scalpel bit into the poor thing's head." Comment on the premedical-training attitude of the high school biology teacher responsible is superfluous but acrid.

Such facets of training as conciseness of statement, erect posture, clear sincere eyes, meaningful activities and conversations, and a tendency to search for underlying causes occupy the thinking of educators interested in the development of the student as a personality. "Little" things, such as spelling and pronunciation, may conceivably alter the career potential of a person in later professional work, for one would need to be a great authority indeed to surmount laughter and ridicule on the lecture platform. As our consideration of method and means of measurement is undertaken, let us give thought to the fact that it may be of lesser importance that high school students be taught *what* to think than it is that they be taught *how* to think, in terms of the scientific method and attitude toward science.[2]

Objectives

Major aims, in addition to understanding and mastery of the scientific method of approach, include general character development, increasing knowledge and technical skill,[3] and adequate preparation for life under conditions of war and peace in the world, together with motivation for future studies as opportunity affords itself in the field of science education as students progress through the secondary grades. College studies may be postponed because of military service; but if America is to survive in the final struggle, there will be continued and increased need for medical and scientific technicians, as well as for scientists devoting their attention to pure and applied disciplines. Hence, the foundational motivation for such life expansion must be provided.

Measurement will not only concern itself with degree of satisfaction in terms of collegiate requirements, but it will encompass the needs of science education for the hundreds of thousands each year who do not and will not go on to higher education. Criteria of diagnosis in the latter case may be even more critically applied, for in such a terminal program of science education the future enlightenment of voting, fighting, and working citizens will be accomplished through media such as the weekly or monthly magazine, the motion picture, the radio, the television program, and the newspaper. Science assimilation, orientation, and mastery evaluation must go beyond the subject test to include analysis of degree of impact of modern environment *in toto* upon student personality, if reactions preparatory to life's practical and aesthetic situations are to be approved or improved, prior to assumption of position in society as soldier, citizen, voter, homemaker, and parent.

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[2] Refer to discussion in Chap. 2, Science and the Scientific Method.

[3] Use of the "pretest" as a yardstick of progress measurement is discussed in Angell, George W., and Rasor, William W., "Next Steps in Evaluation," *The Science Teacher*, Vol. XVII, No. 5, December, 1950.

Correlation

The science educator must guard against a natural tendency to draw up boundary walls about himself, his subjects, and his students, for his own basic aims to be achieved in full measure must be correlated with the ideals of others in an integrated, over-all school program, school objectives taking a degree of precedence over course objectives. Diederich[4] recommends a faculty committee to supervise the evaluation program, on which administrative-group science educators would of course have representation. A primary purpose of the present chapter will be to provide the science instructor with a background of selective measurement information in terms of his special field.

Selection from behavioral situations and observational techniques may be made in attempts to approximate truth in measurement, in addition to and supplementary to the more formal achievement tests listed by subjects. Means of sampling[5] similar to some of those included in the following pages have been professionally adapted by the American Institute of Public Relations, Lloyd's of London, and the scientifically controlled Kinsey reports. *Measurement of ability through performance* has meaning above and beyond the examination paper, written under duress and in an artificial school environment. In undertaking correlative and cooperative surveys of student progress, the science instructor will select from and adapt the following instruments:

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[4] Diederich, Paul B., "Design for a Comprehensive Evaluation Program," *The School Review*, Vol. LVIII, No. 4, April, 1950.

[5] Stephan, Frederick F., "Sampling," *The American Journal of Sociology*, Vol. LV, No. 4, January, 1950.

I. Nonstandardized Instruments of Measurement

The Trap Situation

The semisadistic attitude which is implied here has a legitimate function in determining degree of genuine mastery, and is made use of in situations indicating analytical benefit in all higher education, from the high school to the oral examination for the university Ph.D. degree. A bland, impassive or steadily pleasant expression is maintained by the examiner, even when statements made are grossly incorrect. Thus the student is allowed to reveal his weaknesses. It must be borne in mind that many high school (and college) students become exceedingly adept at reading facial expressions, hence a "poker face" is a decided asset in the trap situation.

As such an attitude upon the part of the instructor is understood, students become wary of placing too much faith in faces rather than in facts and are seldom caught off guard. In our high school and college game of American football such an operation is known to the players as "mousetrapping," and no lineman of experience dashes into a hole that opens too readily for him! He has learned through bitter experience that he may be "cross-blocked" out of the play if he falls into such a trap situation, remaining in a prone position while the opponent's ball carrier dashes through the place where he once stood.

Students who have real mastery *know* when they are right and develop admirable tenacity in defending their point of view. Others in the class listen attentively in order to be aware of errors, instead of watching the teacher for his reaction as a guide. Praise of a student who has "stuck to his guns" always has permanent stimulating value; indeed it may play considerable part in character training for life. Students learn not to speak in order to please the teacher; they speak the *truth*.

Trap situations may be devised in the classroom and in the field. On field trips the teacher occasionally may surmise the location of a certain species of plant, for instance, among a group of small rocks. (The plant is known to have limited local distribution elsewhere and has been studied as such by the class.) A few students may look up, surprised, or may catch the instructor's eye and wink with quiet intelligence. Some students will look for a few moments among the group of rocks before remembering what they have studied. Others would look frantically among all the rocks in the field, until they fell from sheer exhaustion, unless someone stopped them. The trap situation makes a motivating game of intelligence and is a socializing and integrating force which pays dividends on individual alertness and scientific accuracy.

The Questionnaire

This is an information-obtaining device, but an instrument of measurement, nevertheless. It is useful at the beginning of a secondary science unit of study, and also at the end of such a division of the term's work, in evaluating student reaction as well as the degree to which basic objectives have been achieved. Specific questions may be asked, or comments and criticisms requested. Indeed, the author has for many years made a practice, via the questionnaire, of asking for informal anonymous criticisms of his own work in the classroom, which are handed in typewritten, written in "backhand," or otherwise disguised, and unsigned, while he is out of the classroom. Results in the high school situation are not always pleasant reading, but they are usually illuminating in terms of procedures and reactions. Every teacher should summon the moral courage to do this occasionally, as a frank step toward consistent professional growth.

An *alumni* questionnaire would prove extremely beneficial in evaluating science education of secondary grade within the framework of our teacher-training institutions. Questions such as the following should be asked of every certificated graduate, anonymous replies being requested. There will be a few vindictive replies, of course, but the over-all picture will prove worthy of study and thought:

When did you graduate?
Where do you teach? (section of the state only)
What subjects?
Do you employ secondary activity units?
Do you now teach by formal methods?
Do you follow a school core curriculum?
To what extent do you make use of the system course of study in your subject?
Did you personally have a part in formulating this course of study? Do you know teachers who did?
Do you now make use of your college science textbooks in your work? If so, which ones?
Did you have a class in science methods while in college?
Do you now make use of your college textbook on science educational methods? In what ways?
Do you use the visual and laboratory aids, including files and notebooks you constructed while in college?
What type of material do you wish you had in those files and notebooks that is not there?
Do you use a printed syllabus or workbook?
Do you use your own mimeographed syllabus or localized workbook with your classes in high school?
Do you do much field collecting or observing in your present situation? Where (type of place) do you go, or why don't you go?
What college or university courses in science do you find to be of most practical benefit *now*? Why?
Which science course do you now use least? Why?
Which science teachers did you personally like best while you were in college? Why?
Which science teachers do you *now* appreciate the most at your alma mater? Why?
Please give us the benefit of your field experience. What constructive suggestions are you willing to make which would,

in your opinion, tend to improve training for secondary school science teaching?

Performance Tests

The student may be asked to go to the board, and there outline a problem and its solution. A student may be requested to ask another student a question on material subject matter previously studied by the class. This procedure has double merit, for the ability to ask intelligent, pertinent questions is one mark of an educated man or woman. Students may all stand up and ask each other "spelldown" questions, either for grades or for fun, with good psychological results in either case. Procedure is essentially the same as in the old-fashioned "spelling match," except that subject-matter questions are employed rather than words. After democratically choosing sides from class personnel, a brief period for team preparation is provided, usually about five minutes. During such a period all sources of information may be employed, including text and notebooks. When beginning time is announced, all students (and instructor) stand without notes, the student teams facing each other across the laboratory. The leader on one side asks the leader on the other a subject-matter question. If the opponent cannot answer correctly, he must *sit down*. If he has missed the question, it goes to the next in line. If the question is answered correctly, the student answering has the turn to ask a question of the next in line of the first side.

The instructor is judge, jury, and referee, his decisions being final. The team having the most students *standing* at the end of the time agreed upon wins, all members receiving a grade of A in recitation for the day. All members of the losing team who remain standing receive B grades. Those sitting down on the winning side receive C grades, while those on the losing side, sitting down, all get D marks for the day's recitation.

Students love this little device; it establishes socialization and *esprit de corps* in the classroom as few other things will.

Grades do not count so much that losers are unhappy, and new teams chosen at various times provide the spirit of competition American young people like. Take this ancient pedagogical device from the shelf some rainy day, dust it off a bit, changing "spelling" to "science-subject-matter" rivalry, and put it to work in your own modern classroom laboratory. Results are guaranteed.

Nonobjective (Essay) Examinations

General measurements may be made with this instrument, and the author believes that if questions have been properly prepared it will show good discrimination; however, this feature is usually considered the weakest point of the essay test. The same trained reader (in the high school, it will usually be the teacher himself) should evaluate all answers. A factor is the grading of but one question at a time, through all the set of papers. Too many nonobjective tests should not be read at any one time, as fatigue is also a factor. Essay examinations allow a wide degree of latitude in coverage, which raises lesser segregation of outcomes as an objection. Objectivity is not a primary aim, however, or one of the objective tests would have been employed. Sampling is not so complete as in other types, if similar time limits are imposed. In brief, essay tests have a place in semifinal or final surveys, in measuring larger outcomes, attitudes, interest, and grade-subject progress.

Multiple-choice Recognition

This type is not difficult to construct,[6] and many teachers make frequent use of it at all grade levels. The optional choice permits the weighing of relative facts and judgment on the basis of evidence presented, itself a desirable objective from the viewpoint of scientific method. The danger of ambiguity must be avoided if good results are expected.

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[6] Woodburn, John, "Constructing Machine Scorable Examinations in the Natural Sciences," *The Science Teacher,* Vol. XVII, No. 5, December, 1950.

Examples of adequate multiple-choice recognition questions are the following:

DIRECTIONS: In the groups of statements below, one statement is true in each group; the others are false. Place a check opposite the true statement.

	Check One
1. Most marine chlorophyll-bearing plants are known as "fungi."	______
Most marine chlorophyll-bearing plants are known as "lichens."	______
Most marine chlorophyll-bearing plants are known as "algae."	X
Most marine chlorophyll-bearing plants are known as "seed plants."	______
2. All seaweeds are "algae."	______
All algae are seaweeds.	______
All seaweeds are "kelp."	______
All seaweeds are "aquatic."	X

True-False Recognition

These tests are among the "trickiest" to organize, if they are carefully done, and much depends upon their organization, for unless carefully checked they may contain answer clues. Contrary to the general impression with regard to short questions, brief statements of fact are often true in scientific fields. Here again ambiguous statements are to be avoided. For example, one of the following statements is less suitable than the other:

Lead is heavier than aluminum of equal bulk. [✓ T] F
Lead is lighter than aluminum of equal bulk. T [✓ F]

In the latter sentence, the term "lighter" may readily be construed to mean lighter in *color*, and freshly cut lead *is* lighter in color than oxidized aluminum.

Another danger, omnipresent in the secondary school, is that of *guessing*, and true-false tests of less than one hundred questions are not advisable for this reason. Approximately an equal number of true and untrue statements should be presented. One or two so-called shock-absorbing questions may be inserted at the start, in order to calm students and to give confidence, and obvious untruths or truths may well be used here. Directions must be carefully given as to the circling of T or F answers and as to time allowed. Exemplary questions will illustrate:

DIRECTIONS: Circle the T or the F following each statement below:

All algae are marine. T [✓ F]
Spirogyra is a brown alga. T [✓ F]
Ulva may be called "sea lettuce." [✓ T] F
Sargassum is a genus of "Gulfweed." [✓ T] F
No algae grow in the ocean below a depth of seven hundred feet. [✓ T] F
All red algae are red in color. T [✓ F]

Matching Recognition

In administering matching tests, three things are of primary importance. First, a clear description of the situation must be given. Second, directions must be concise and definite. Third, the content should be homogeneous. For example, in testing recall and association at the end of a chemical section of general science, directions similar to the following may be given:

> BELOW ARE GIVEN A NUMBER OF CHEMICAL COMPOUNDS, AND A NUMBER OF CHEMICAL FORMULAE. ON THE LINE OPPOSITE EACH FORMULA, PLACE THE NUMBER OF THE COMPOUND YOU ASSOCIATE WITH IT.
>
> (1) *Water.* (2) *Salt.* (3) *Sulphuric acid.* (4) *Hydrogen peroxide.*

H_2SO_4 *3* H_2O_2 *4* H_2O *1* $NaCl$ 2

Recall Objective Tests

The completion or "fill-in" recall objective examination, if constructed with care, may cover almost as wide an area in a given period of time (sampling) as the true-false type, and may demonstrate greater validity and reliability as well. Groups of about fifty questions are advisable in the secondary school science class. Examples of the utilization of this instrument form are given below, with relation to general science, chemistry, or biology:

1. *Lavoisier* was the chemist who actually named the element "oxygen."
2. The presence of carbon dioxide (CO_2) in human lung exhalation may be demonstrated by bubbling exhaled breath through *lime water* .
3. *Schleiden* and *Schwann* first advanced the "cell theory" in the year *1839* .
4. The process of food manufacture in the leaves of green plants is known as *photosynthesis* .
5. The four chemical elements found in greatest abundance in plant and animal bodies are *Hydrogen* , *Carbon* , *Oxygen* , and *Nitrogen* .

The Open-book Examination

As an instrument measuring long-term objectives and the basic aims of science education, this form is difficult to excel. There are certain disadvantages such as low discrimination (according to some teachers), although the author has made frequent use of this method in junior high, senior high and college, obtaining a normal distribution curve in practically every instance. Lack of specific memory training for dates and for facts is a further disadvantage. These points, however, may easily be checked in other ways and are far outweighed by the wide sampling, high validity, and extreme objectivity of this method. Added to these are the intangible factors of student satisfaction, the feeling of getting a "square deal," and the atmosphere of practical life situations, which are so evident.

Students of secondary school age frequently do not remember much of the mass of factual information which is poured into them longer than is necessary to pass the several term examinations, as all educators know. Furthermore, many boys and girls whisper to one another, passing on information, or peek at written answers to examination forms easily read, such as true-false and completion. The open-book test permits every student to bring any and all references and sources into the classroom with him, at one stroke eliminating all tendency toward bad character training.

In addition, the open-book test most closely approaches the situations of social living. For instance, consider the young teacher himself, preparing to teach his first classes. He looks up facts and figures, to check his memory, and makes certain of formulae and key words. He himself has learned *where to find* accurate information pertinent to the specific science problems at hand, and he is able quickly and effectively to apply his knowledge in terms of use.

It is this very efficiency in terms of immediate functional need that this instrument measures. About twenty-five questions at an individual rating of 4 per cent give very valid qualitative results in secondary school classes, to the satisfaction of all concerned. Even those embryonic scientists who do not score high are personally dissatisfied with *their own* inaccuracies and coverage of sources, never with the test itself as a fair measurement. *Time* is, of course, the key factor, since almost anyone may find answers if given enough time. The idea is to prove ability to locate useful facts within a given period, which implies extreme familiarity with the subject and with pertinent references.

The Laboratory Notebook

Here the student's chemical equations, apparatus sketches, and flat mounted specimens are assembled for evaluation of the instructor, and for the future use of the student in school and in life. Both in terminal ninth-grade instruction and throughout the high school, much time may be spent on this visual aid, and it deserves careful evaluation. Integration of mimeographed or printed loose-leaf manual pages, where these have been made available, will give good results and will stimulate careful preparation of the student's own work. Although recent studies reveal adequate coverage through teacher demonstrations, there can be no real substitute for laboratory work in the "learn-by-doing" philosophy of learning; and where this is subscribed to, the laboratory notebook will give evidence of quality and quantity of attainment.

Reaction to New Situations

Measurement of reaction training has its place in all science subjects of the secondary school. After an extended period of instruction during which students have assimilated factual information concerning method of study and content of a unit, each boy or girl may be assigned to a definite problem situation and instructed to organize, within a given time limit, an outline for dealing with it. Such an assignment brings into play all of each student's past learning and present creative ability and reasoning, placing a premium upon quick thinking, deduction, and adaptation to environmental circumstances.

Sight Recognition

This is a socialized adaptation of the matching recognition test and has validity as an instructing as well as a measuring device. Holding up specimens in life-science or in physical science class for written identification, or having the entire class move as individuals on signal from one numbered, unlabeled specimen to another are examples. Later the papers may, if the instructor desires, be corrected by the students themselves, with information sources open and field specimens at hand. Indeed, such a sight-recognition test may actually be given in the field, should occasion warrant.

Comprehensive Review

This may be oral or written, but it is best conducted orally in the secondary school, as a personal interview with each individual. This summary review must, of necessity, come late in the semester. It will reveal a great many things, including the larger outcomes of the training program in science, together with an indication of the elements of philosophical maturation in terms of comprehension of reasons *why* subjects have been studied, and their sequence.

The Cumulative Record

Such a record, revealing within itself, should be kept as follows:

Name: Jones, Mary Elizabeth.
Address: 1766 Prospect Avenue.
Telephone: Davenport 28317.
Entered from: Horace Mann Junior High.
Rating: Recommended by principal.
Parent or guardian: Franklin D. Jones.
Parent's occupation: Dentist.

Testing data: Chronological age (C.A.): 14
Mental age (M.A.): 16
Physical age (P.A.): 13
Social age (S.A.): 12

Extracurricular activities: Girls' Glee Club (Grades 10 and 11.) Song leader (Grade 11. Does not wish to be song leader again.) Brownies' camp counselor (juniors) Grade 10. (Did not go to camp the next year.)

School interests: Science, instrumental music (piano) personal voice. Has unusual collection of local pressed wild flowers.

Departmental science courses: Hygiene (Grade 7) Miss Davis. Grades B – A. General Physical Science (Grade 8)

Mr. March. Grades A – A. Social Biology (Grade 10) Mr. Hansen. Grades A – A.

Supplementary information: Works after school and on Saturday mornings this year under supervision of Mr. Hall, in Museum of Natural History.

Counseling recommendations: Hard-working, serious, conscientious girl. Almost *too* conscientious, for her age. Needs socializing influences for best development. College preparatory; probably teacher training.

SUMMARY IN TERMS OF FUNCTIONAL USE

The fourteen nonstandardized instruments of diagnostic measurement so far presented are among those most widely utilized in American secondary schools. Application of the principles and recommendations set forth in the analysis of each form will have two desirable outcomes, with specific relation to science education. First, through the continuous evaluation of many teachers, the diagnostic program will reveal the nature of each student's maturation with regard to science aptitude and science content,[7] while providing a systematic check on instruction methods as well as testing. Second, such procedures will reveal both good and bad points of this phase of the total educational experience, with relation to the whole personality. This, in turn, will influence the attainment of two other valid objectives: the constant improvement of secondary school teaching techniques, and the ultimate improvement of student behavior patterns with respect to scientific knowledge and research endeavor. Such a long-range program will thus tend to provide over-all measurement of ability as well as performance.

The more formal evaluation instruments enumerated in the following section are grouped by subject headings as well as by grades. The author is personally of the opinion that each of the standardized tests which follow has its place in good secondary school teaching as well as in efficient supervision of effort. This place, however, must surely be defined most carefully in terms of *a checking instrument for informative purposes, with regard to broad areas of coverage,* in sequence. No secondary schoolroom or laboratory measurement is conclusive which does not take into account the basic aims, background, scope, prior training, and social elasticity of each individual student, teacher, room, group, and system course of study.

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[7] See Prognostic Tests for Secondary Education, in the following section on Standardized Instruments of Measurement.

II. STANDARDIZED INSTRUMENTS OF MEASUREMENT

DIAGNOSTIC TESTS FOR SUBJECT MASTERY

General Science

Application of Principles of General Science. Grades 9–12. Progressive Education Association.

Beauchamp Tests on Everyday Problems in Science. Grades 9–12. Scott, Foresman & Company.

Calvert Science Information Test. Grades 8–9. California Test Bureau.

Cause-and-effect Relationships in Science. Grades 9–10. E. M. Hale & Company, Publishers.

Cooperative General Science Test. Grades 10–12. Cooperative Test Service.

Dvorak General Science Scales. Grades 7–9. Public School Publishing Company.

Dvorak-Wagenen Analytical Scales in Elementary Science (Division 4). Grade 9. Educational Test Bureau.

Glenn-Gruenberg Instrüctional Tests in General Science. Grades 7–9. World Book Company.

National Achievement Tests in General Science. Grades 7–9. Acorn Publishing Company.

Powers General Science Test. Grades 7–9. Bureau of Publications, Teachers College, Columbia University.

Ruch-Popenoe General Science Test. Grades 7–9. World Book Company.

Science Information Test.[5] Grades 7–9. California Test Bureau.

Biology

Blaisdell Instructional Tests in Biology. Grades 9–11. World Book Company.

Cooperative Biology Test. Grades 9–11. Cooperative Test Service.

Cooperider Information Exercises in Biology. Grades 9–10. Public School Publishing Company.

Hanes-Benz Biology Test. Grades 9–10. C. A. Gregory Company.

Michigan Botany Test. Grades 10–11. Public School Publishing Company.

Oakes and Powers Test of General Biology. Grades 10–11. Teachers College, Bureau of Publications, Columbia University.

Presson Biology Test. Grades 9–10. World Book Company.

Ruch-Cossman Biology Test. Grades 9–12. World Book Company.

Williams Biology Test. Grades 9–10. Bureau of Educational Measurements, Kansas State Teachers College.

Chemistry

Clinton-Osborn-Ware General Chemistry Test. Grades 11–12. Oregon State College Cooperative Association.

Columbia Research Bureau Chemistry Test. Grades 11–12. World Book Company.

Cooperative Chemistry Test. Grades 11–12. Cooperative Test Service.

Gerry Test of High School Chemistry. Grades 11–12. Ginn & Company.

Glenn-Walton Chemistry Achievement Test. Grades 11–12. World Book Company.

Harvard Chemistry Tests. Grades 11–12. C. A. Gregory Company.

Iowa Placement Examinations; Chemistry Training. Grades 11–12. Bureau of Educational Research, University of Iowa.

Morneweck-Buckner-Kirschner General Achievement Test in Chemistry. Grades 11–12. Educational Test Bureau.

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[5] Hattery, Lowell, "Why Waste Talent?" *School and Society*, Vol. 71, No. 1834, Feb. 11, 1950.

Powers General Chemistry Test. Grades 11–12. World Book Company.

Rich Chemistry Test. Grades 11–12. Public School Publishing Company.

Physics

Application of Principles of Physical Science. Grades 11–12. Progressive Education Association.

Camp-Iowa Physics Test. Grades 11–12. Public School Publishing Company.

Columbia Research Bureau Physics Test. Grades 11–12. World Book Company.

Cooperative Physics Achievement Test. Grades 11–12. Cooperative Test Service.

Fulmer-Schrammel Physics Test. Grades 11–12. Bureau of Educational Measurements, Kansas State Teachers College.

Glenn-Osborn Instructional Tests in Physics. Grades 11–12. World Book Company.

Hughes Physics Scales. Grades 11–12. Public School Publishing Company.

Hurd Test in Physics. Grades 11–12. Teachers College, Bureau of Publications, Columbia University.

Kirkpatrick-Greene Objective Test Exercises in Physics. Grades 11–12. Public School Publishing Company.

Sangren-Marburger-Michigan Instructional Tests in Physics. Grades 11–12. Public School Publishing Company.

Stewart-Ashbaugh Physics Test. Grades 11–12. Public School Publishing Company.

Torgerson-Rich-Ranney Test in Physics. Grades 11–12. C. A. Gregory Company.

Wisconsin Achievement Test in Physics. Grades 11–12. E. M. Hale & Company, Publishers.

Prognostic Tests for Secondary Education [9]

American Council on Education Psychological Examination for Freshmen. Thurstone and Thurstone; American Council on Education. Two forms, hand or machine scored. Time, 52 minutes for each form. Verbal and quantitative subjects. Norms from a large college freshman population.

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[9] Prognostic tests are valuable in teacher-training institutions and are of great assistance to supervisors and interested teachers with regard to aptitudes generally, including science education.

Bell Adjustment Test. Hugh M. Bell; Stanford University Press. Emotional, home social and health forms.

California Tests of Mental Maturity. Sullivan, Clarke, Tiegs; California Test Bureau. Two batteries, elementary and advanced. The former is useful in grade 9, the advanced battery in grade 12. Hand or machine scored.

California Test of Personality. Thorpe, Clarke, Tiegs; California Test Bureau. Valuable diagnostic as well as prognostic material, measurement of social adjustment. Percentile charts accompany.

Coxe-Orleans Prognosis Test of Teaching Ability. World Book Company. Reliable and valid. Recommended for use with secondary school grades 10, 11, and 12.

Gentry Vocational Inventory. Educational Test Bureau. Gives a general vocational picture in terms of eight primary vocational groups. Recommended for use in grade 12 and with college freshmen.

Gregory Academic Interest Inventory. Sheridan Supply Company. Scores twenty-eight vocational interests, including biological sciences, chemistry, physics, and the general area of secondary education. Grade 12 and college freshmen.

Kefauver-Hand-Block Guidance Tests. World Book Company. Tests for health, vocations, sociocivic reactions, recreation, and education. A valuable series in terms of secondary science education.

Kuder Preference Record-Vocational. Science Research Associates, Chicago. Measures the fundamental areas of educational and vocational interest, including mechanical, musical, computational, scientific, persuasive, artistic, literary, social service, and clerical. Useful in grade 12 and with college freshmen.

Morris Trait Index L. Public School Publishing Company. Measures aptitude for secondary school teaching. Prepared for use with high school seniors and college freshmen.

Odell-Herriott Standard Achievement Test on Principles of Teaching in Secondary Schools. Public School Publishing Company. Prognostic through diagnostic measurement of achievement and comprehension. An eight-page instrument designed for use in teacher-training institutions.

Strong Vocational Interest Tests. Stanford University Press. Widely used and recognized; reliable and valid. For high school students, grades 11 and 12; may be used in grade 10. Measures maturity of interest, masculinity and femininity, studious habit, and surveys possible occupations.

Symonds-Block Student Questionnaire. Bureau of Publications, Teachers College, Columbia. Covers, with probing insight, student relationship to school administration, supervision, curriculum and grading, as well as social interrelationships.

Weber Standard Achievement Test on Aims, Purposes, Objectives, Attributes and Functions in Secondary Education. Public School Publishing Company. Prepared for use in the selection, guidance, and training of high school teachers. Prognosis through measurement of ability in terms of performance.

PART II

RESOURCE AIDS

AUDIO-VISUAL INSTRUCTIONAL MATERIALS

COLOR SLIDES (2 BY 2 INCHES)

American Council on Education, 744 Jackson Pl., N.W., Washington 6, D.C.

Audio-Visual Service, 209 Civic Center, San Diego 1, Calif.

Bowman Slide Company, 2067 Broadway, New York 23.

Bureau of Visual Instruction, Extension Division, State University of Iowa, Iowa City, Iowa.

California Biological Service, 1612 W. Glenoaks Blvd., Glendale 1, Calif.

Chicago Apparatus Co., 1735 N. Ashland Ave., Chicago.

Coronet Instructional Films, Inc., 919 N. Michigan Ave., Chicago 9.

Denoyer-Geppert Company, 5235–5259 Ravenswood Ave., Chicago 40.

General Biological Supply House, 761 E. 69th Pl., Chicago 37.

Long Filmslide Service, 944 Regal Rd., Berkeley 8, Calif.

Nesbit Color Slides, 711 Columbia Rd., Colorado Springs, Colo.

Philip Photo Visual Service, 1218 American Ave., Long Beach 13, Calif.

Society for Visual Education, Inc., 100 E. Ohio St., Chicago 11.

Ward's Natural Science Establishment, 3000 Ridge Road East, Rochester 9, N.Y.

Young America Films, Inc., 18 E. 41st St., New York 17.

FILMSTRIPS [1]

American Council on Education, 744 Jackson Pl., N.W., Washington 6, D.C.

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[1] See Falconer, Vera M., *Filmstrips*, McGraw-Hill Book Company, Inc., 330 W. 42d St., New York 36, and the *Filmstrip Guide*, H. W. Wilson Company, 950 University Ave., New York 52.

American Films Registry, 28 E. Jackson Blvd., Chicago 4.
American Forest Products Industries, 1319 Eighteenth St., N.W., Washington 6, D.C.
American Gas Association, 420 Lexington Ave., New York 17.
American Museum of Natural History, 79th St. and Central Park West, New York 24.
American National Livestock Assn., Press Bldg., Sheridan, Wyo.
American Potash Institute, 1155 Sixteenth St., N.W., Washington 6, D.C.
American Society for Metals, 7301 Euclid Ave., Cleveland 3, Ohio.
American Telephone and Telegraph Co., Information Dept., Film and Display Div., 195 Broadway, New York 7.
Associated Film Artists, 30 N. Raymond Ave., Pasadena 1, Calif.
Association of American Railroads, School Service Div., Transportation Bldg., Washington 6, D.C.
Association for Childhood Education International, 1200 Fifteenth St., N.W., Washington 5, D.C.
Audio-Visual Aids Co., 712 Ramayne Ave., Racine, Wis.
Audio-Visual Enterprises, 4405 Springdale Dr., Los Angeles 43.
Audio-Visual Extension Service, City College, Midtown Business Center, 430 W. 50th St., New York 19.
Audio-Visual Materials Consultant Bureau, College of Education, Wayne University, Detroit 1.
Australian News and Information Bureau, 630 Fifth Ave., New York 20.
Barr Productions, 1265 Bresee Ave., Pasadena 7, Calif.
Bates Manufacturing Co., 30 Vesey St., New York 7.
Bennett Co., Inc., 237 N. Monroe St., Peoria, Ill.
Better Light Better Sight Bureau, 420 Lexington Ave., New York 17.
Bowman Company, 513 W. 166th St., New York 32.
Bray Studios, Inc., 729 Seventh Ave., New York 19.
Bryant Foundation, 737 N. Edgmont St., Los Angeles 27.
Bureau of Communications Research, Inc., 13 E. 37th St., New York 16.
California Institute of Technology, Public Relations Dept., 1201 E. California St., Pasadena 4, Calif.
Civil Aeronautics Admin., Audio-Visual Training Aids Staff, A-165 Commerce Bldg., Washington 25, D.C.

Coast Visual Education Co., 6058 Sunset Blvd., Hollywood 28, Calif.
Commonwealth Pictures Corp., 723 Seventh Ave., New York 19.
Congress of Industrial Organization, Film Div., Dept. of Ed. and Research, 718 Jackson Pl., N.W., Washington 6, D.C.
Consumer Educational Films, 18 E. 41st St., New York 17.
Coronet Instructional Films, 65 E. South Water St., Chicago 1.
Cory Corporation, 221 N. La Salle St., Chicago 1.
Council on Atomic Implications, Inc., Box 296, University of Southern California, Los Angeles 7.
Creative Arts Studio, Inc., 1200 Eye St., N.W., Washington 5, D.C.
Current Affairs Films, 18 E. 41st St., New York 17.
Cutler Laboratories, 4th and Parker Sts., Berkeley 10, Calif.
Dartnell Corp., 4660 Ravenswood Ave., Chicago 40.
De Frenes Company, 1909 Buttonwood St., Philadelphia 30.
Eastman Kodak Stores, Inc., Kodascope Libraries Div., 356 Madison Ave., New York 17.
Edited Pictures System, Inc., 165 W. 46th St., New York 19.
Educational Film Service, 180 N. Union St., Battle Creek, Mich.
Educational Services, 1702 K St., N.W., Washington 6, D.C.
E. I. du Pont de Nemours & Company, Inc., Advertising Dept., 10th and Market Sts., Wilmington 98, Del.
Encyclopaedia Britannica Films, Inc., 1150 Wilmette Ave., Wilmette, Ill.
Esso Standard Oil Co., 15 W. 51st St., New York 19.
Eye Gate House, Inc., 330 W. 42d St., New York 18.
Felmette Filmstrips, 700 Riverside Dr., New York 31.
Film Research Associates, 135 W. 52d St., New York 19.
Filmsets, Inc., 1956 N. Seminary Ave., Chicago 14.
Filmstrip House, 25 Broad St., New York 4.
Florez, Inc., 815 Bates St., Detroit 26.
Franco-American Audio-Visual Distribution Center, Inc., 934 Fifth Ave., New York 21.
Fresh'nd-Aire Co., 221 N. La Salle St., Chicago 1.
General Electric Company, Visual Education Div., 1 River Rd., Schenectady 5, N.Y.
General Motors Corporation, Dept. of Public Relations, Film Dist. Section, 3044 W. Grand Blvd., Detroit 2.
Gessler Publishing Co., Hastings-on-Hudson, N.Y.

Girl Scouts of America, Visual Education Service, 155 E. 44th St., New York 17.

Gymer Company, 2123 E. 9th St., Cleveland 15, Ohio.

Harmon Foundation, Inc., 140 Nassau St., New York 7.

Hawaii Press Bureau, 1040 National Press Bldg., Washington 4, D.C.

Heidenkamp Nature Pictures, 538 Glen Arden Dr., Pittsburgh 8.

Hoefler Productions, 612½ S. Ridgeley Dr., Los Angeles 13.

Holst and Company, 332 E. Walnut St., Pasadena 1, Calif.

Household Finance Corporation, 919 N. Michigan Ave., Chicago 11.

Illustravox Division, The Magnavox Company, Bueter Road, Fort Wayne 4, Ind.

Indiana University Audio-Visual Center, 1800 E. 10th St., Bloomington, Ind.

Informative Classroom Pictures Publishers, 40 Ionia Ave., N.W., Grand Rapids 2, Mich.

International Ladies Garment Worker's Union, Educational Dept., 1710 Broadway, New York 19.

Jam Handy Organization, 2821 E. Grand Blvd., Detroit 11.

John Wiley & Sons, Inc., Filmstrips Division, 440 Fourth Ave., New York 16.

Kayfetz Productions, 130 E. 56th St., New York 22.

Knowledge Builders, 625 Madison Ave., New York 22.

Laidlaw Brothers, Inc., 221 Fourth Ave., New York 3.

Lederle Laboratories Division, American Cynamid Company, 30 Rockefeller Plaza, New York 20.

Library Films, Inc., 25 W. 45th St., New York 19.

Life Magazine, Time, Inc., 9 Rockefeller Plaza, New York 20.

Long Filmslide Service, 944 Regal Rd., Berkeley 8, Calif.

The Macmillan Company, Visual Education Dept., 60 Fifth Ave., New York 11.

McCormick and Company, Inc., McCormick Bldg., Baltimore 2.

McGraw-Hill Book Company, Inc., Text-Film Dept., 330 W. 42d St., New York 36.

Massachusetts Institute of Technology, Division of Audio-Visual Aids, 69 Massachusetts Ave., Cambridge 39, Mass.

Medical Research Film Library, 1569 Broadway, Brooklyn 7.

Metropolitan Life Insurance Co., 1 Madison Ave., New York 10.
Mirror Manufacturers' Association, 435 N. Michigan Ave., Chicago 11.
Mogull Bros., Inc., 112–114 W. 48th St., New York 19.
Nash-Kelvinator Corporation, Kelvinator Div., Film Section, 14250 Plymouth Rd., Detroit 32.
National Audubon Society, 1000 Fifth Ave., New York 28.
National Commission of Safety Education, National Education Assn., 1201 Sixteenth St., N.W., Washington 6, D.C.
National Dairy Council, 111 N. Canal St., Chicago 6.
National Education Association, 1201 Sixteenth St., N.W., Washington 6, D.C.
National Foundation for Infantile Paralysis, 120 Broadway, New York 5.
National Safety Council, 425 N. Michigan Ave., Chicago 44.
New Haven Railroad, Public Relations Dept., 490 S. Station, Boston 10.
New York Times, School Service Dept., 229 W. 43d St., New York 18.
New York Zoological Society, 185th St. and Southern Blvd., New York 60.
Ohio Farm Bureau, 246 N. High St., Columbus 16, Ohio.
Operadio Manufacturing Company, Saint Charles, Ill.
Photo and Sound Productions, 116 Natoma St., San Francisco 5, Calif.
Pic Films, Inc., 117 W. 48th St., New York 19.
Pictorial Films, Inc., 625 Madison Ave., New York 22.
Pilgrim Press, 14 Beacon St., Boston 8.
Poultry and Egg National Board, 308 W. Washington St., Chicago 6.
Public Affairs Committee, Inc., 22 E. 38th St., New York 16.
The Queen's Work, 3115 S. Grand Blvd., St. Louis 18.
Row, Peterson & Company, 1911 Ridge Ave., Evanston, Ill.
Santa Fe Film Bureau, 80 E. Jackson Blvd., Chicago 4.
Science Research Associates, 228 S. Wabash Ave., Chicago 4.
Science Slides Co., 22 Oak Dr., New Hyde Park, N.Y.
Shell Oil Company, Inc., Public Relations Dept., 50 W. 50th St., New York 20.
Sonotone Corporation, Education Dept., P.O. Box 200, Elmsford, N.Y.

Standard Oil Company of New Jersey, 30 Rockefeller Plaza, New York 20.

Standard Publishing Co., 20 E. Central Parkway, Cincinnati 10, Ohio.

Sugar Information, Inc., 52 Wall St., New York 5.

Texas Forest Service, College Station, Tex.

Trindl-King Filmstrips, 5050 Petit Ave., Encino, Calif.

United States Dept. of Agriculture, Extension Service, Washington 25, D.C. (for information only). Purchase orders direct to: Photo Lab Inc., 3825 Georgia Ave., N.W., Washington 11, D.C.

United States Office of Education, Audio-Visual Aids Div., Federal Security Agency, Washington 25, D.C.

United World Films, Inc., 1445 Park Ave., New York 29.

Visual Education Libraries, Visual Education Center, Floral Park, Long Island, N.Y.

Visual Education Service, Yale University, 409 Prospect St., New Haven 11, Conn.

Vocafilm Corporation, 424 Madison Ave., New York 17.

Westinghouse Electric Corporation, Film Library, 317 Blvd. of the Allies, Pittsburgh 30.

Whittemore Associates, Inc., Dept. of Visual Aids, 16 Ashburton Pl., Boston 8.

Wild Flower Preservation Society, 3740 Oliver St., N.W., Washington 15, D.C.

Young America Films, Inc., Filmstrips Division, 18 E. 41st St., New York 17.

LANTERN SLIDES (3¼ BY 4 INCHES)

Chicago Apparatus Company, 1735 N. Ashland Ave., Chicago 22.

Coronet Instructional Films, 65 E. South Water St., Chicago 1.

Denoyer-Geppert Company, 5235 Ravenswood Ave., Chicago 40.

Eastman Educational Slides Company, Iowa City, Iowa.

General Biological Supply House, 761 E. 69th Pl., Chicago 37.

Keystone View Company, Meadville, Pa.

National Audubon Society, 1000 Fifth Ave., New York 28.

National Geographic Society, Sixteenth and M Sts., N.W., Washington 6, D.C.

MODELS

American Dental Association, 222 E. Superior St., Chicago 11.

American Forest Products Industries, Public Relations Dept., 1319 Eighteenth St., N.W., Washington 6, D.C.

American Institute of Steel Construction, Inc., Dept. of Educational Services, 101 Park Ave., New York 17.

American Petroleum Institute, 50 W. 50th St., New York 20.

American Potash Institute, 115 Sixteenth St., N.W., Washington 6, D.C.

Atlantic Refining Company, 260 S. Broad St., Philadelphia 2.

Bausch and Lomb Optical Company, 635 Saint Paul St., Rochester 2, N.Y.

Bell and Zoller Coal Company, Advertising Dept., 307 N. Michigan Ave., Chicago 1.

Carborundum Company, Niagara Falls, N.Y.

Cast Iron Pipe Research Association, 122 S. Michigan Ave., Chicago 3.

Central Scientific Company, 1700 Irving Park Rd., Chicago 13.

Champion Spark Plug Company, Toledo 1, Ohio.

Chicago Tribune Public Service Office, Tribune Bldg., Chicago 11.

Clay-Adams Company, Inc., 44 E. 23d St., New York 10.

Denoyer-Geppert Company, 5235 Ravenswood Ave., Chicago 40.

Eastman Kodak Company, 343 State St., Rochester 4, N.Y.

E. I. du Pont de Nemours & Company, Inc., Advertising Dept., Empire State Bldg., New York 1.

Ford Motor Company, Advertising Dept., Schaefer Rd., Dearborn, Mich.

General Biological Supply House (Turtox models), 761 E. 69th Pl., Chicago 37.

General Electric Company, Public Relations Dept., Schenectady 5, N.Y.

General Mills, Inc., 400 Second Ave., South Minneapolis 1, Minn.

General Motors Corporation, Broadway at 57th St., New York 19.

Goodyear Tire and Rubber Company, Inc., Akron 16, Ohio.

Illinois Education Association, 100 E. Edwards St., Springfield, Ill.

International Harvester Company, Consumer Relations Dept., 180 North Michigan Ave., Chicago 1.

Jewell Models, Carlinville, Ill.

Johnson and Johnson, New Brunswick, N.J.

Mallinckrodt Chemical Works, 70–74 Gold St., New York 8.

New York Scientific Supply Company, Inc., 28 W. 30th St., New York 1.

Nystrom and Company, 3333 Elston Ave., Chicago 18.

Owens-Illinois Glass Company, Toledo 1, Ohio.

Pittsburgh Plate Glass Company, Public Relations Dept., 632 Duquesne Way, Pittsburgh 22.

Shell Oil Company, Inc., Public Relations Dept., 50 W. 50th St., New York 20.

Society for Visual Education, Inc., 100 E. Ohio St., Chicago 11.

Standard Oil Company, Public Relations Dept., 910 S. Michigan Ave., Chicago 80.

Swift and Company, Merchandising Service Dept., Union Stock Yards, Chicago 9.

Ward's Natural Science Establishment, Inc., 3000 Ridge Rd. East, Rochester 9, N.Y.

W. M. Welch Scientific Company, 1515 Sedgwick St., Chicago 10.

Western Electric Company, 195 Broadway, New York 7.

Westinghouse School Service, Westinghouse Electric Corp., 306 Fourth Ave., Pittsburgh 30.

MOTION PICTURES [2]

A and M College of Texas, Department of Audio-Visual Aids, College Station, Tex.

A. F. Films, Inc, 1600 Broadway, New York 19.

Abelard Educational Films, Inc., 1440 Broadway, New York 18.

Academy Films, Ltd., P.O. Box 3088, Hollywood, Calif.

Air World Education, 101 W. 11th St., Kansas City 6, Mo.

A-I Talking Pictures Service, 1734 S. Vermont Ave., Los Angeles 8.

Akin and Bagshaw, Inc., 2023 E. Colfax Ave., Denver 6, Colo.

Allen and Allen Productions, 3947 W. 59th Pl., Los Angeles 43.

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[2] See *The Blue Book of 16-mm. Films,* Educational Screen, Inc., 64 E. Lake St., Chicago 1; also *The Educational Film Guide,* The H. W. Wilson Company, 950 University Ave., New York 52.

All-State Pictures, 39 W. Adams St., Chicago 3.

American Automobile Association, Traffic Engineering and Safety Dept., Pennsylvania Ave., at Seventeenth St., Washington 6, D.C.

American Brass Company, Advertising Dept., Waterbury 88, Conn.

American Cyanamid Company, Coating Resins Dept., Rockefeller Plaza, New York 20.

American Film Library, 394 W. San Carlos St., San Jose 10, Calif.

American Film Services, 1010 Vermont Ave., N.W., Washington 5, D.C.

American Heart Association, 1775 Broadway, New York 19.

American Petroleum Institute, 50 W. 50th St., New York 17.

Arizona State College Film Library, Tempe, Ariz.

Association Films, 19 S. La Salle St., Chicago 3.

Audio-Visual Supply Company, 1224 E St., Sacramento 14, Calif.

Bailey Films, Inc., 2044 N. Berendo St., Hollywood 27, Calif.

Bayley Films, Inc., 2044 N. Berendo St., Hollywood 27, Calif.

Better Vision Institute, 630 Fifth Ave., New York 20.

Bowman Dairy Company, 140 W. Ontario St., Chicago 10.

Brandon Films, Inc., 1700 Broadway, New York 19.

Breskin Publishing Company, Film Booking Dept., 122 E. 42d St., New York 17.

Bureau of Visual Instruction, University Extension Division, University of Wisconsin, Madison, Wis.

California Barr Productions, 1265 Bresee Ave., Pasadena 7, Calif.

Capitol Film Service, 224 Abbott Rd., East Lansing, Mich.

Castle Films; United World Films, Inc., 1445 Park Ave., New York 19.

Churchill-Wexler Film Productions, 137 N. La Brea Ave., Los Angeles 36.

Cine-Crafts, 8764 Beverly Blvd., Los Angeles 48.

Classroom Films, Inc., 1585 Broadway, New York 19.

Climax Molybdenum Company, 500 Fifth Ave., New York 18.

Coast Visual Education Company, 6058 Sunset Blvd., Hollywood 28, Calif.

Commercial Films, Inc., P.O. Box 7, Cleveland 21, Ohio.

Coronet Instructional Films, 65 E. South Water St., Chicago 1.

Council on Atomic Implications, Inc., Box 296, University of Southern California, Los Angeles 7.

Cultural Films, Inc., 62 William St., New York 5.

Current Affairs Films Division, Key Production, Inc., 18 E. 41st St., New York 17.

Current History Films, 226 E. 22d St., New York 10.

Curriculum Films, 14–17 Crescent Blvd., Long Island City 1, N.Y.

Dairy Council of St. Louis, 4030 Chouteau Ave., St. Louis, Mo.

Davey Tree Expert Company, Kent, Ohio.

Dennis Film Libraries, 2508 W. 7th St., Los Angeles 5.

Depilto Films, Inc., 254 W. 54th St., New York 19.

Eberle Tanning Company, Westfield, Pa.

Encyclopaedia Britannica Films, Inc., 1150 Wilmette Ave., Wilmette, Ill.

Film Highlights, Inc., 1697 Broadway, New York 19.

Filmfax Productions, 10 E. 43d St., New York 17.

Film Publishers, Inc., 25 Broad St., New York 4.

Films, Inc., Instructional Div., 330 W. 42d St., New York 18.

Fish and Wildlife Service, U.S. Dept. of the Interior, Washington 25, D.C.

Flory Films, Inc., 303 E. 71st St., New York 21.

Ford Motor Company, Film Library, Schaefer Rd., Dearborn, Mich.

Foundation Films Corp., Citizens Bank Bldg., Pasadena 1, Calif.

Gateway Production, Inc., 930 Market St., San Francisco 5.

General Electric Company, Visual Education Div., 1 River Rd., Schenectady 5, N.Y.

General Mills Film Library, 400 Second Ave. South, Minneapolis 1.

General Motors Corporation, Public Relations Dept., Broadway at 57th St., New York 19.

General Pictures Productions, Inc., 621 Sixth Ave., Des Moines 9, Iowa.

Hardcastle Films, 818 Olive St., St. Louis 1, Mo.

Hawley-Lord, Inc., 61 W. 56th St., New York 19.

Heidenkamp Nature Pictures, 538 Glen Arden Dr., Pittsburgh 8.

Hollywood-Pan American Films, 5356 La Mirada Ave., Hollywood 27, Calif.

Huntington Laboratories, Inc., Huntington, Ind.

Ideal Pictures Corporation, 2408 W. 7th St., Los Angeles 5.

Institute of Life Insurance, Education Dept., 60 E. 42d St., New York 17.
Instructional Film Bureau, 6 N. Michigan Ave., Chicago 2.
International Film Bureau, 6 N. Michigan Ave., Chicago 2.
International Harvester Company, Inc., 180 N. Michigan Ave., Chicago 1.
International Theatrical and Television Corporation of the West, 3123 W. 8th St., Los Angeles 5.
Jam Handy Organization, 2821 E. Grand Blvd., Detroit 11.
McGraw-Hill Book Company, Inc., Text-Film Dept., 330 W. 42d St., New York 36.
Mallinckrodt Chemical Works, Second and Mallinckrodt Sts., St. Louis 7, or 70–74 Gold St., New York 8.
Maryfilms, 410 S. Beverly Dr., Beverly Hills, Calif.
Medical Research Film Library, 1569 Broadway, Brooklyn 7.
Merkee Films Library, 1734 Pacific Ave., Long Beach, Calif.
Modern Talking Picture Service, 9 Rockefeller Plaza, New York 20.
National Audubon Society, 1000 Fifth Ave., New York 28.
National Education Association, 1201 Sixteenth St., Washington 6, D.C.
National Film Board of Canada, 400 W. Madison St., Chicago 6.
National Foundation for Infantile Paralysis, Inc., 120 Broadway, New York 5.
National School Service Institute, Shop 307, Palmer House, Chicago 3.
New York State Conservation Dept., Division of Conservation Education, Broadway Arcade Blvd., Albany 7, N.Y.
New York University Film Library, 26 Washington Pl., New York 3.
Olympic Motion Picture Films, 563 Fifteenth St., Oakland 12, Calif.
Pennsylvania State College, Audio-Visual Aids Library, State College, Pa.
Pittsburgh Plate Glass Company, Public Relations Dept., Grant Bldg., Pittsburgh 19.
Porto Movies, 5521 Hollywood Blvd., Hollywood 28, Calif.
Post Pictures Corp., 115 W. 45th St., New York 19.
Ralston Purina Company, 5514 University Way, Seattle 5.

Reed Motion Pictures Service, 8737 Wilshire Blvd., Beverly Hills, Calif.
Research Institute of America, Inc., 292 Madison Ave., New York 17.
RKO Radio Pictures, Inc., 1270 Sixth Ave, New York 20.
Rolab Photo-Science Laboratories, Sandy Hook, Conn.
Royal Typewriter Company, Inc., School Dept., 2 Park Ave., New York 16.
Scientific Film Company, 6804 Windsor Ave., Berwyn 1, Ill.
Shell Oil Company, Inc., Public Relations Dept., 50 W. 50th St., New York 20.
Skibo Productions, Inc., 165 W. 46th St., New York 19.
Society for Visual Education, Inc., 1345 W. Diversey Parkway, Chicago 14.
Society of the Plastics Industry, Inc., 295 Madison Ave., New York 17.
Spaulding and Brothers, Inc., 1137 S. Hope St., Los Angeles 15.
Sterling Films, Inc., 316 W. 56th St., New York 19.
Teachers College, Bureau of Publications, Columbia University, 525 W. 120th St., New York 27.
Telenews Productions, Inc., 1859 Powell St., San Francisco 11.
United States Forest Service, Motion Picture Service, U.S. Dept. of Agriculture, Washington 25, D.C.
United World Films, Inc., 1445 Park Ave., New York 19.
University of California, Dept. of Visual Instruction, University Extension, Berkeley 4, Calif.
Van Camp Sea Food Company, Inc., 228 N. La Salle St., Chicago 1.
Visual Aid Service, 1086 El Camino Real, Menlo Park, Calif.
Wartburg Film Service, Inc., Wartburg College, Waverly, Iowa.
Weather Bureau, Motion Pictures Dept., U.S. Department of Commerce, Washington 25, D.C.
Western Pine Association, Yeon Bldg., Portland 4, Ore.
Wurtele Film Productions, P.O. Box 154, Orlando, Fla.
Young America Films, Inc., 18 E. 41st St., New York 17.

TEXT-FILMS

Breskin Publishing Company, Film Book Dept., Chanin Bldg., 122 E. 42d St., New York 17.

Illinois Education Association, 100 E. Edwards St., Springfield, Ill.

McGraw-Hill Book Company, Inc., Text-Film Dept., 330 W. 42d St., New York 36.

Society for Visual Education, Inc., 100 E. Ohio St., Chicago 11.

Young America Films, Inc., 18 E. 41st St., New York 17.

COMMERCIAL SOURCES OF EQUIPMENT AND SUPPLIES

Ace Glass, Inc., Glass Apparatus, Vineland, N.J.
Adolph Frese Corporation, Instruments and Apparatus, 116 W. 17th St., Los Angeles 15.
Ainsworth and Sons, Balances, 2151 Lawrence St., Denver, Colo.
Alberene Stone Corporation of Virginia, 419 Fourth Ave., New York 16.
Allied Chemical and Dye Corporation, 40 Rector St., New York 6.
Allied Radio Company, 833 W. Jackson Blvd., Chicago 7.
Aloe Apparatus Company, 19th and Olive Sts., St. Louis 3.
Aluminum Company of America, 1032 Oliver Bldg., 535 Smithfield St., Pittsburgh 19.
American Cynamid Company, 30 Rockefeller Plaza, New York 20.
American Electrical Sales Company, 67 E. 8th St., New York 3.
American Felt Company, 58 Glenville Rd., Glenville, Conn.
American Instrument Company, 8030–8050 Georgia Ave., Silver Spring, Md.
American Machine and Metals, Inc., East Moline, Ill.
American Seating Company, 9th St. and Broadway, Grand Rapids, Mich.
Angel and Company, Inc., 52 Duane St., New York 7.
Arapahoe Chemical Company, Inc., 2800 Pearl St., Boulder, Colo.
Arma Electrical Corporation, 254-36th St., Brooklyn 32.
Arrow-Hart and Hegeman Electric Company, 103 Hawthorn St., Hartford 6, Conn.
Atomic Instrument Company, 84 Massachusetts Ave., Cambridge 39, Mass.
Bacharach Industrial Instrument Company, 7000 Bennett St., Pittsburgh 8.

Baker and Company, Platinum Ware, 113 Astor St., Newark 5, N.J.

Baltimore Biological Laboratory, Inc., 1640 Gorsuch Ave., Baltimore 18.

Bausch and Lomb Optical Company, 771 St. Paul St., Rochester 2, N.Y.

Bendix Aviation Corporation, Friez Instrument Division, 1422 Taylor Ave., Baltimore 4.

Biddle and Company, Laboratory Supplies, 1316 Arch St., Philadelphia 7.

Biological Research Products Company, 3829 S. Morgan St., Chicago 9.

Braun Corporation, 2260 E. 15th St., Los Angeles 21.

Brooklyn Botanic Garden, 1000 Washington Ave., Brooklyn 25.

Brooklyn Thermometer Company, Springfield Gardens, N.Y.

Brownscope Company, Binoculars, 24 W. 45th St., New York 19.

Brush Development Company, Industrial Instruments and Crystals, 3405 Perkins Ave., Cleveland 14, Ohio.

Buehler Ltd., Metallurgical Equipment, 165 W. Wacker Dr., Chicago 1.

Buhl Optical Company, 1009 Beech Ave., Pittsburgh 12.

Burrell Technical Supply Company, 1936 Fifth Ave., Pittsburgh 19.

California Biological Service, Inc., 1612 W. Glenoaks Blvd., Glendale 1, Calif.

California Wiping Material Company, 58 White St., New York 13.

Cambosco Scientific Company, 37 Antwerp St., Brighton 35, Boston, Mass.

Cambridge Instrument Company, Inc., 3749 Grand Central Terminal, New York 17.

Carbide and Carbon Chemicals Division, Union Carbide and Carbon Corporation, 30 E. 42d St., New York 17.

Cargilla Scientific Products, 118 Liberty St., New York 6.

Carl Schleicher & Schuell Company, Filter Papers, 116–118 W. 14th St., New York 11.

Carolina Biological Supply Company, Elon College, N.C.

Castolite Company, Plastic Imbedding Supplies, Woodstock, Ill.

Central Scientific Company, 1700 Irving Park Road, Chicago 13.

Chemical Rubber Company, 2310 Superior Ave., Cleveland 14, Ohio.

Chicago Apparatus Company, 1735 N. Ashland Ave., Chicago 22.

Chicago Wheel & Manufacturing Company, 1101 W. Monroe St., Chicago 7.

Clark Instrument Company, Inc., 102000 Ford Rd., Dearborn, Mich.

Clay-Adams Company, Anatomical Models, 141 E. 25th St., New York 10.

Clebar Watch Co., 551 Fifth Ave., New York 17.

Coe-Palm Biological Supply House, 1126 N. Milwaukee Ave., Chicago 22.

College Biological Supply Company, 9230 Woodlawn Ave., Seattle 3.

Commercial Solvents Corporation, 17 E. 42d St., New York 17.

Consolidated Engineering Corporation, Electronic Instruments, 620 N. Lake Ave., Pasadena 4, Calif.

Coors Porcelain Company, Golden, Colo.

Corning Glass Works, Laboratory Sales Department, Corning, N.Y.

Cutler-Hammer, Inc., Electrical Equipment & Wiring Devices, 315 N. 12th St., Milwaukee 1, Wis.

Davison Chemical Corporation, Baltimore 3.

Denoyer-Geppert Company, 5235 Ravenswood Ave., Chicago 40.

Difco Laboratories, Inc., Dehydrated Culture Media & Reagents, Detroit 1.

Distillation Products Industries, Eastman Organic Chemicals, 751 Ridge Road West, Rochester 3, N.Y.

Dodge & Olcott, Inc., Essential Oils, 180 Varick St., New York 14.

Dougherty Chemicals, 87-34 134th St., Richmond Hill 18, N.Y.

Dow Chemical Company, Midland, Mich.

Dow Corning Corporation, Plastics & Silicones, Midland, Mich.

Driver-Harris Company, Electrical Alloys, Harrison, N.J.

Ducommun Metals and Supply Company, 580 Fifth Ave., New York 19.

Dumont Laboratories, Inc., Oscillographs and Cathode-ray Tubes, Passaic, N.J.

Eastern Chemical Company, 34 Spring St., Newark 2, N.J.

Eastman Kodak Company, 343 State St., Rochester 4, N.Y.

Edcan Laboratories, 10–20 Pine St., So. Norwalk, Conn.

Edmund Salvage Company, Optical Supplies, 101 E. Gloucester Pike, Barrington, N.Y.

Eimer and Amend Company, Greenwich and Morton Sts., New York 14.

Electric Hotpack Co., Inc., Cottman Ave. at Melrose St., Philadelphia 35.

El-tronics, Inc., 2647 Howard St., Philadelphia 33.

Emil Greiner Company, 161 Sixth Ave., New York 13.

Erb & Gray Company, Scientific & Optical Instruments, 854 S. Figueroa St., Los Angeles 14.

Ercona Corporation, Carl Zeiss, Jena Instruments, 527 Fifth Ave., New York 17.

Fenwal Incorporated, Thermoswitch Controls, Ashland, Mass.

Fireye Corporation, 77 Broadway, Cambridge 42, Mass.

Fisher Scientific Supply Company, 717 Forbes St., Pittsburgh 19.

Flexitallic Gasket Company, Eighth and Bailey Sts., Camden 2, N.J.

Foxboro Company, Thermocouples & Accessories, Foxboro, Mass.

Gaertner Scientific Corporation, Microscope Equipment and Spectrometers, 1201 Wrightwood Ave., Chicago 14.

Galigher Company, Inc., Microscopic Slides, P.O. Box 63, Albany Station, Berkeley, Calif.

General Aniline and Film Corporation, 444 Madison Ave., New York 22.

General Biochemicals, Inc., 677 Laboratory Park, Chagrin Falls, Ohio.

General Biological Supply House, 761–763 E. 69th Pl., Chicago 37.

General Chemical Company, 40 Rector St., New York 6.

General Controls Company, 801 Allen Ave., Glendale 1, Calif.

General Electric Company, Schenectady 5, N.Y.

General Electric X Ray Corporation, 2021 Jackson Blvd., Chicago 4.

General Radio Company, 275 Massachusetts Ave., Cambridge 39, Mass.

General Science Service, 1927 Hennepin Ave, Minneapolis 5.

Glas-Col Apparatus Company, Inc., 1700 S. 7th St., Terre Haute, Ind.

Gradwohl Laboratories, Reagent Specialties, 3514 Lucas Ave., St. Louis 3.

Graf-Apsco Company, Rebuilt Microscopes, 5868 Broadway, Chicago 40.

Graybar Electric Company, 420 Lexington Ave., New York 17.

Greiner Glassblowing Laboratory, 255 W. Santa Barbara St., Los Angeles 37.

Hamilton Bell Company, Inc., Dissecting Sets & Supplies, 310 Atlantic St., Paterson 3, N.J.

Harry Ross, Scientific Apparatus, 70 W. Broadway, New York 7.

Harshaw Scientific Division, Harshaw Chemical Company, 1945 E. 97th St., Cleveland 6, Ohio.

Hartman-Leddon Company, Inc., Reagent Specialties, 5821 Market St., Philadelphia 39.

Harvard Apparatus Company, Physiological Experimental Apparatus, Dover, Mass.

Hathaway Instrument Company, 1315 S. Clarkson St., Denver 10, Colo.

Haydon Manufacturing Company, Inc., 245 E. Elm St., Torrington, Conn.

H-B Instrument Co., Inc., 2518 N. Broad St., Philadelphia 32.

Hevi Duty Electric Company, Milwaukee 1, Wis.

Hoke Incorporated, Regulators & Valves, Englewood, N.J.

Hooker Electrochemical Company, 9-47th St., Niagara Falls, N.Y.

Houston Technical Laboratories, 2424 Branard St., Houston 6, Texas.

Ilex Optical Company, Shutters and Lenses, Rochester 5, N.Y.

Industrial & Scientific Instrument Company, 430 E. Allegheny Ave., Philadelphia 34.

Insulation Manufacturer Corporation, 565 W. Washington Blvd., Chicago 6.

International Resistance Company, Power Resistance Equipment, 417 N. Broad St., Philadelphia 8.

Ivan Sorvall, Laboratory Apparatus, 210 Fifth Ave., New York 10.

Jarrell-Ash Company, Optical Instruments, 164 Newbury St., Boston 16.

Kelly-Koett Manufacturing Company, Scientific Instruments, 24 E. Sixth St., Covington, Ky.

Kimble Glass, Laboratory Glassware, P.O. Box 1035, Toledo 1, Ohio.

Kinney Manufacturing Company, Vacuum Pumps, 3583 Washington St., Boston 30.

Laboratory Construction Company, 1115 Holmes St., Kansas City 6, Mo.

Lambda Electronics Corporation, 103 Northern Blvd., Corona, N.Y.

Lapine and Company, 121 W. Hubbard St., Chicago 10.

Leeds & Northrup Instrument Company, 4978 Stenton Ave., Philadelphia 44.

Leeman Bros., Inc., Pumps & Motors, P.O. Box 1339, Newark, N.J.

Los Angeles Biological Laboratories, Aquarium Tanks and Accessories, 2977 W. 14th St., Los Angeles 6.

Los Angeles Scientific Instrument Company, 108 W. Sixth St., Los Angeles 14.

Machlett and Son, Apparatus and Supplies, 220 E. 23d St., New York 10.

Mallinckrodt Chemical Works, Second and Mallinckrodt Sts., St. Louis 7.

Marsh Corporation, Thermometers, Stokie, Ill.

The Matheson Company, Organic Chemicals, East Rutherford, N.J.

Merck & Company, Inc., Chemicals, Rahway, N.J.

Meriam Instrument Company, 1955 W. 112th St., Cleveland 20, Ohio.

Metalab Equipment Corporation, 1532 Dean St., Brooklyn 13.

Metal Hydrides, Inc., 12–24 Congress St., Beverly, Mass.

Meta-Magnet Associates, Electromagnet Equipment, P.O. Box 3664, Orlando, Fla.

Meylan Stop Watch Company, 264 W. 49th St., New York 18.

Microchemical Specialties Company, 1834 University Ave., Berkeley 3, Calif.

Milliuse Instrument Company, P.O. Box 3027, New Haven, Conn.

Modern Science Labs, 8049-A St. Clair Ave., North Hollywood, Calif.

Monsanto Chemical Company, 1700 S. Second St., St. Louis 4.

Mueller Company, Brass Instruments, Decatur, Ill.

Multiplex Display Fixture Company, 911–921 N. Tenth St., St. Louis 1.

Nalge Chemical Equipment Company, 623 Goodman St. South, Rochester 20, N.Y.

National Appliance Company, Swan Island, Portland 18, Ore.

National Biological Supply Company, 4836 Foster Ave., Chicago 30.

National Manufacturers, Certified Stains, 40 Rector St., New York 6.

New York Scientific Supply Company, 28 W. 30th St., New York 1.

North American Philips Company, Inc., X Ray Precision Diffraction Units, 750 S. Fulton Ave., Mt. Vernon, N.Y.

Norton Company, Laboratory Ware, Worcester, Mass.

Nuclear Instrument and Chemical Corporation, 223–233 W. Erie St., Chicago 10.

Nurnberg Thermometer Company, 394 Bridge St., Brooklyn.

Nystrom and Company, Science Teaching Charts, 3333 Elston Ave., Chicago 18.

Oregon Biological Supply Company, 303 N.E. Multnomah St., Portland 12, Ore.

Pacific Laboratory Apparatus Company, 3555 Whittier Blvd., Los Angeles 23.

Perkin-Elmer Corporation, Scientific Instruments, Glenbrook, Conn.

Perkins Machine & Gear Company, West Springfield, Mass.

Permutit Company, Ion Exchangers, 330 W. 42d St., New York 18.

Pfanstiehl Chemical Company, Waukegan, Ill.

Phipps & Bird, Inc., 303 S. Sixth St., Richmond, Va.

Plummer and Kershaw, Precision Optics, 2761 Frankford Ave., Philadelphia 34.

Precision Equipment Company, 3708 N. Milwaukee Ave., Chicago 41.

Precision Optical Supply Company, 1001 E. 163d St., New York 59.

Precision Scientific Company, 3737 W. Corland St., Chicago 47.

Precision Thermometer & Instrument Company, 1434 Brandywine St., Philadelphia 30.

Presto Recording Corporation, 242 W. 55th St., New York 19.

Pulverizing Machinery Company, Chatham Rd., Summit, N.J.

Quivira Specialties Company, Biological Specimens, 4010 W. 21st St., Topeka 28, Kan.

Radiac Company, Geiger-Mueller Counters and Radioactivity Demonstrators, 489 Fifth Ave., New York 17.

Radio Corporation of America, Electronic and Radio Equipment, Camden, N.J.

R.E.A. Magnet Wire Company, Fort Wayne, Ind.

Revere Copper and Brass, Inc., 230 Park Ave., New York 17.

Ross Allen's Reptile Institute, Reptile Skins, Satchels, and Cages, Silver Springs, Fla.

Ross Scientific Apparatus, 70 W. Broadway, New York 7.

Sargent & Company, 165 E. Superior St., Chicago 11.

Schaar and Company, Chemical Supplies, 754 W. Lexington St., Chicago 7.

Schick Publishing Company, Anatomical Charts, 700 Riverside Dr., New York 31.

Science Associates, Meteorological Supplies, 401 N. Broad St., Philadelphia 8.

Seedburo Equipment Company, 618 W. Jackson Blvd., Chicago 6.

Selas Corporation of America, Scientific Equipment, Erie Ave. and D St., Philadelphia 34.

Spencer Chemical Company, Dwight Building, Kansas City 6, Mo.

Sprague Electric Company, Electronic and Electric Equipment, North Adams, Mass.

Standard Scientific Supply Corporation, 34 W. Fourth St., New York 12.

Stratex Instrument Company, 1861 Hillhurst Ave., Los Angeles 27.

Statham Laboratories, Scientific Instruments, 9328 Santa Monica Blvd., Beverly Hills, Calif.

Superior Electric Company, Bristol, Conn.

Taber Instrument Company, North Tonawanda, N.Y.

Technology Instrument Corporation, Waltham, Mass.

Testa Manufacturing Company, School Microscopes, 418 S. Pecan St., Los Angeles 33.

Todd Scientific Company, Springfield, Pa.

Tracertab, Inc., Radioactivity Equipment, 130 High St., Boston 10.

Triarch Botanical Products, Botanical Slides, George H. Conant, Ripon, Wis.

Triplitt Electrical Instrument Company, Bluffton, Ohio.

United Binocular Company, 9043 S. Western St., Chicago 20.

United Scientific Company, 200 N. Jefferson St., Chicago 6.

Universal Scientific Company, Inc., Vincennes, Ind.

Universal Steel Equipment Corporation, 33-47th Ave., Long Island 1, N.Y.

Vacuumate Corporation, 446 W. 43d St., New York 18.

Virginia Smelting Company, Chemical Supplies, West Norfolk, Va.

Ward's Natural Science Establishment, 3000 Ridge Road East, Rochester 9, N.Y.

Weber Costello Company, Sinusoidal Projection Maps, Chicago Heights, Ill.

Welch Scientific Company, 1515 Sedgwick St., Chicago 10.

Western Felt Works, 4029 Ogden Ave., Chicago 23.

Westinghouse Electric Corporation, 306 Fourth Ave., Pittsburgh 30.

The H. A. Wilson Company, Thermometals, 105 Chestnut St., Newark, N.Y.

Windsor Biology Gardens, 316 W. Third St., Bloomington, Ind.

Woods Hole Marine Biological Laboratory, Supply Dept., Woods Hole, Mass.

Worthington Biochemical Laboratory, P.O. Box 591, Freehold, N.J.

MAGAZINES USEFUL IN SECONDARY SCIENCE EDUCATION

American Forests, American Forestry Association, 910 Seventeenth St., N.W., Washington 6, D.C.

Aminco Laboratory News, American Instrument Company, Inc., 8030 Georgia Ave., Silver Spring, Md.

Aquarium, Innes Publishing Company, 129 N. 12th St., Philadelphia 7.

Audubon, National Audubon Society, 1000 Fifth Ave., New York 28.

Bios, Frank G. Brooks, Cornell College, Mount Vernon, Iowa.

Bird Lore, Appleton-Century-Crofts, Inc., 29–35 W. 32d St., New York 1.

Canadian Nature, Audubon Society of Canada, 177 Jarvis St., Toronto 2, Ontario, Canada.

Castanea, Southern Appalachian Botanical Club, West Virginia University, Morgantown, W. Va.

Cenco News Chats, Central Scientific Company, 1700 Irving Park Rd., Chicago 13.

Chemical Abstracts, The American Chemical Society, Ohio State University, Columbus 10, Ohio.

Chemistry, Science Service, 1719 N St., N.W., Washington 6, D.C.

Cornell Rural School Leaflets, New York State College of Agriculture, Extension Division, Cornell University, Ithaca, N.Y.

Current Science, Current Science Magazine, 40 S. Third St., Columbus, Ohio.

Ecology, Ecological Society of America, Duke University Press, P.O. Box 6697, College Station, Durham, N.C.

Electronics, McGraw-Hill Publishing Company, Inc., 330 W. 42d St., New York 36.

Eugenical News, American Eugenics Society, 1790 Broadway, New York 19.

Field and Stream, Field and Stream Publishing Company, 515 Madison Ave., New York 22.

Hunting and Fishing, Hunting and Fishing Publishing Company, 275 Newbury St., Boston 16.

Industrial and Engineering Chemistry, The American Chemical Society, 1155 Sixteenth St., N.W., Washington 6, D.C.

Journal of Applied Physics, American Institute of Physics, 57 E. 55th St., New York 22.

Laboratory, Schaar and Company, 754 W. Lexington St., Chicago 7.

Life, Time, Inc., 540 N. Michigan Ave., Chicago 11.

Living Wilderness, Wilderness Society, 1840 Mintwood Pl., Washington, D.C.

Monsanto Magazine, Monsanto Chemical Company, 1700 South Second St., St. Louis 4.

Monthly Evening Sky Map, Celestial Map Publishing Company, 244 Adams St., Brooklyn 1.

National Geographic Magazine, National Geographic Society, 1146 Sixteenth St., N.W., Washington 6, D.C.

Natural History, American Museum of Natural History, 79th St., at Central Park West, New York 24.

Nature, American Nature Association, 1214 Sixteenth St., N.W., Washington 6, D.C.

Outdoors Illustrated, National Audubon Society, 1000 Fifth Ave., New York 28.

Popular Mechanics, Popular Mechanics Company, 200 E. Ontario St., Chicago 11.

Popular Science Monthly, Popular Science Publishing Company, 353 Fourth Ave., New York 10.

Progressive Education, American Education Fellowship, 27 N. Jackson St., Danville, Ill.

Radio Age, Department of Information, Radio Corporation of America, 30 Rockefeller Plaza, New York 20.

Recreation, National Recreation Association, 315 Fourth Ave., New York 10.

Reviews of Modern Physics, Prince and Lemon St., Lancaster, Pa.

School Science and Mathematics, P.O. Box 408, Oak Park, Ill.

Science, Science Magazine, American Association for the Advancement of Science, 1515 Massachusetts Ave., N.W., Washington 5, D.C.

Science and Society, Science and Society, Inc., 20 E. 30th St., New York 3.

Science Digest, Science Digest Magazine, Inc., 200 E. Ontario St., Chicago 11.

Science Education, Science Education, Inc., 374 Broadway, Albany, N.Y.

Science Education News, School Science Council, American Academy of Arts and Sciences, 28 Newberry St., Boston 16.

Science in Steelmaking, Research and Public Relations Dept., United States Steel Corporation Subsidiaries, 429 Fourth Ave., Pittsburgh 19.

Science News Letter, Science Service, 1719 N St., N.W., Washington 6, D.C.

Scientific American, Scientific American, Inc., 24 W. 40th St., New York 18.

Sky and Telescope, Sky Publishing Corporation, Harvard College Observatory, Cambridge 38, Mass.

Skyways, Skyways Magazine, Henry Publishing Company, 444 Madison Ave., New York 22.

Sports Afield, Sports Afield Company, 1200 Hodgson Bldg., Minneapolis 1.

Steelways, American Iron and Steel Institute, 350 Fifth Ave., New York 1.

The American Biology Teacher, N. Queen St. and McGovern Ave., Lancaster, Pa.

The Educational Focus, Bausch and Lomb Optical Company, Rochester 2, N.Y.

The Laboratory, Fisher Scientific Company, 717 Forbes St., Pittsburgh 19.

The Quarterly Review of Biology, The Williams & Wilkins Company, Mount Royal and Guilford Aves., Baltimore 2.

The Science Teacher, National Science Teachers Association, 1201 Sixteenth St., N.W., Washington 6, D.C.

The Scientific Monthly, American Association for the Advancement of Science, 1515 Massachusetts Ave., N.W., Washington 5, D.C.

Time (sections on Science), Time, Inc., 540 N. Michigan Ave., Chicago 11.

Travel, R. M. McBride and Company, 116 E. 16th St., New York 3.

Turtox News, General Biological Supply House, 761 E. 69th Pl., Chicago 37.

Ward's Natural Science Bulletin, Ward's Natural Science Establishment, 3000 Ridge Road East, Rochester 9, N.Y.

Wild Flower, Wild Flower Preservation Society, 3740 Oliver St., N.W., Washington 15, D.C.

PAMPHLETS, PICTURES, AND POSTERS: SOURCES AND ANNOTATIONS [1]

Address	*Annotation*
Air-age Education Research, 1000 E. 42d St., New York 17.	Pamphlet literature of interest to teachers of general science.
Air Transport Association of America, 1107 Sixteenth St., N.W., Washington 6, D.C.	Pamphlets and pictures available to teachers on request, adapted to secondary school use.
Albers Milling Company, 5045 Wilshire Blvd., Los Angeles 36.	Pamphlets on cereals available to teachers of social biology and economic botany.
Aluminum Company of America, Public Relations Dept., 535 Smithfield St., Pittsburgh 19.	Pictures and booklets useful in general science, chemistry, and physics. Information on aluminum and its uses.
American Airlines, Inc., Public Relations Division, 100 E. 42d St., New York 17.	Pamphlets and pictures on air education for classes in general science and physics.

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[1] See Vars, Gordon F., "Getting the Most from Business-sponsored Pamphlets," *The Science Teacher*, Vol. XVII, No. 5, December, 1950.

Address (*continued*)	*Annotation* (*continued*)
American Can Company, Home Economics Dept., 230 Park Ave., New York 17.	Pamphlets for use with biology and zoology classes presenting stories of production of some canned foods.
American Cancer Society, Public Education Division, 47 Beaver St., New York 4.	Authoritatively prepared booklets on cancer education designed for secondary science use.
American Forest Products Industries, 1319 Eighteenth St., N.W., Washington 6, D.C.	Pamphlets, wall maps, and charts showing economic uses of wood.
American Forestry Association, 919 Seventeenth St., N.W., Washington 6, D.C.	Charts and pamphlets on forest education for use by botany instructors.
American Iron and Steel Institute, 350 Fifth Ave., New York 1.	Booklets and pictures on the steel industry for general science, chemistry, and physics.
American Medical Association, Bureau of Health Education, 535 N. Dearborn St., Chicago 10.	Authoritatively prepared publications on health education for use of secondary school teachers.
American Museum of Natural History, Cent. Park West at 79th St., New York 24.	"Man and Nature," a catalogue of scientific publications of the museum suitable for school use.
American Nature Association, 1214 Sixteenth St., N.W., Washington 6, D.C.	Teaching reproductions from *Nature* magazine for secondary science classes. Lists on request.

Address (continued)	*Annotation (continued)*
American Optical Company, Public Relations Dept., Scientific Instrument Div., Buffalo 15.	Photographs, booklets, and charts of educational worth, free to high school science instructors.
American Paper and Pulp Association, 122 E. 42d St., New York 17.	"The Paper Industry" and other informative pamphlet materials for use with botany classes.
American Petroleum Institute, 50 W. 50th St., New York 20.	Pamphlets on products derived from petroleum for use of general science and chemistry teachers.
American Public Health Association, 1790 Broadway, New York 19.	Excellent pamphlets on health education for use with secondary school biology classes.
American Telephone and Telegraph Company, Educational Aids Division, 195 Broadway, New York 7.	"The Magic of Communication," "Miracle Man of the Telephone," and other booklets for use in general science and physics.
American Tree Association, 1214 Sixteenth St., N.W., Washington 6, D.C.	Charts and pamphlets on trees and their conservation, for use of botany and biology students.
American Viscose Corporation, 350 Fifth Ave., New York 1.	Pamphlets detailing the manufacture and uses of viscose and acetate rayon.
American Wool Council, Inc., 1450 Broadway, New York 18.	Pamphlet materials on wool and its uses, for biology and economic zoology classes.

Address (continued)	*Annotation (continued)*
Appalachian Hardwood Manufacturers, 414 Walnut St., Cincinnati 2.	Pamphlets on various uses of wood, of interest to students of social biology and botany.
Armour and Company, Public Relations Dept., Chicago 9.	Large wall charts for classroom use concerning meat products. Suitable for social biology and zoology.
Armstrong Cork Company, 5012 Madison St., Lancaster, Pa.	Pamphlets on cork, linoleum, and flooring materials for use with social biology and botany.
Association of American Railroads, Transportation Bldg., Washington 6, D.C.	Illustrated booklets on rail transport for general science and social biology classes.
Atchison, Topeka and Santa Fe Railway, Public Relations Dept., 80 E. Jackson Blvd., Chicago 4.	Pictures and pamphlets on rail transport for general science and social biology classes. Also useful in socialized physics and senior science.
Audubon Society of Canada, 177 Jarvis St., Toronto 2, Canada.	Conservation and natural history pamphlets of interest to teachers of zoology, botany, and biology, in addition to magazines.
Bausch and Lomb Optical Company, 780L St. Paul St., Rochester 2, N.Y.	"The Educational Focus," bulletin; also wall charts and pamphlets helpful in teaching use of the microscope.

Address (*continued*)	*Annotation* (*continued*)
Better Vision Institute, Inc., 3157 International Bldg., 630 Fifth Ave., New York 20.	Classroom materials on light refraction and optics for general science and physics classes.
Bituminous Coal Institute, Educational Dept., Southern Bldg., Washington 5, D.C.	Pamphlets concerning coal; also demonstration teaching kits, of interest to teachers of general science in the high school.
Borden Company, 350 Madison Ave., New York 17.	Pamphlets and charts on milk for biology student use.
Botany Worsted Mills, Passaic, N.J.	Supplementary materials on wool for economic zoology.
Bristol-Myers Company, Department ST-25, 45 Rockefeller Plaza, New York 20.	Teaching aids on physical fitness, dental health, and personal grooming for high school biology students.
Bureau of Agricultural Chemistry and Engineering, Department of Agriculture, Washington 25, D.C.	Publications for economic botany, biology, and zoology. List available to science teachers on request.
Bureau of Reclamation, Department of the Interior, Washington 25, D.C.	A series of illustrated booklets on government projects in reclamation.
California Conservation Council, 912 Santa Barbara St., Santa Barbara, Calif.	Conservation education pamphlet materials for high school teachers.

Address (continued)	*Annotation (continued)*
California Fruit Growers' Exchange, Educational Division, P.O. Box 5030, Metropolitan Station, Los Angeles.	"The Story of Oranges and Lemons," Sunkist food bulletins, and other teaching aids for biology and botany classes.
California and Hawaiian Sugar Refining Corporation, Ltd., 215 Market St., San Francisco 5.	"Behind Your Sugar Bowl" and other pamphlets, as well as maps, charts, and pictures of sugar production.
Celanese Corporation of America, 180 Madison Ave., New York 16.	Pamphlets and charts on textiles and plastics for general science, chemistry, and physics.
Celotex Corporation, Dept. SP-10, 120 S. La Salle St., Chicago 3.	Pamphlet information on sound conditioning, of interest to students of physics.
Cereal Institute, Inc., 135 S. La Salle St., Chicago 3.	Bulletins and leaflets on cereals for economic botany.
Chicago Natural History Museum, Educational Division, Chicago 5.	Museum stories in leaflet form. Listings free; leaflets, small charge.
Church and Dwight Company, Inc., Department X-62, 10 Cedar St., New York 5.	Pamphlets on oral hygiene and dental care for health education in general science and biology.

Address (continued)	*Annotation (continued)*
Civil Aeronautics Administration, Aviation Education Division, Washington 25, D.C.	Lists of instructional aids for secondary school general science and physics.
Compton's Source Materials for Schools and Teachers, 1000 N. Dearborn St., Chicago 10.	Pamphlets, charts, and booklets. List to teachers on request.
Conservation Foundation, 30 E. 40th St., New York 16.	Pictures and pamphlets on conservation for high school teaching.
Cornell Rural School Leaflets, New York State College of Agriculture, Cornell University, Ithaca, N.Y.	Excellent science leaflets, issued several times each year. Authoritative and interestingly presented ecological studies of eastern flora and fauna.
Corning Glass Works, Corning, N.Y.	Booklets on heat-resisting and chemical glassware.
Council on Atomic Implications, Inc., University of Southern California, 3518 University Ave., Los Angeles 7.	Booklets and pamphlets on atomic science, including "Atomic Attack—Manual for Survival." List of services and pamphlets on request.
Cream of Wheat, Public Relations Dept., 730 Stinson Blvd., Minneapolis 13.	Pamphlets and food charts useful for nutritional studies in social biology, as well as in economic botany.
Crown Zellerbach Corporation, 343 Sansome St., San Francisco 19.	Informative pamphlet teaching materials on paper and its uses, for economic botany and social biology.

Address (*continued*)	*Annotation* (*continued*)
Dairy Council of St. Louis, 4030 Chouteau Ave., St. Louis 10.	Pamphlets and charts on milk and dairy products for health education and biology classes.
Delta Air Lines, Public Relations Division, Atlanta, Ga.	Maps, bulletins, and charts on air transport free to teachers of junior-senior high school science.
De Vry Corporation, School Service Division, 1111 Armitage Ave., Chicago 14.	School Service Bulletins on audio-visual aids; bibliography and suggestions.
Dow Chemical Company, Public Relations Dept., Midland, Mich.	Reference materials on the six hundred Dow products for industrial chemistry.
Dupont: E. I. du Pont de Nemours & Company, Inc., Public Relations Dept., 1007 Market St., Wilmington 98, Del.	Charts, pamphlets, and posters on rayon, nylon, and plastics, free to secondary science educators.
Eastman Kodak Company, Public Relations Dept., Rochester 4, N.Y.	Charts, bulletins, and pamphlets on photography for general science and physics.
Evaporated Milk Association, 307 N. Michigan Ave., Chicago 1.	List of many pamphlet publications, available free to biology teachers.
Fish and Wildlife Service, Department of the Interior, Washington 25, D.C.	Bulletins discussing care, propagation, control, and conservation of fish, birds, and wild animals.

Address (continued)	*Annotation (continued)*
Florida Citrus Commission, Public Relations Division, Lakeland, Fla.	Pamphlets on oranges and grapefruit, free to biology and botany teachers.
Friends of the Land, 1368 N. High St., Columbus 1, Ohio.	Conservation materials for secondary school science teaching.
Game Conservation Society, Inc., 1819 Broadway, New York 23.	Pamphlets and pictures on mammal and bird conservation.
Garden Club of America, 15 E. 58th St., New York 22.	Leaflets and charts for conservation projects of high school classes.
General Biological Supply House, 761–763 E. 69th Pl., Chicago 37.	"Turtox Service Leaflets," an excellent series, free on request.
General Electric Company, Public Relations Dept., Nela Park, Cleveland, Ohio.	Pamphlet materials on light, for use in general science and physics.
General Electric Company, Educational Service, Schenectady 5, N.Y.	Materials for instruction in general science and physics.
General Mills, Inc., Education Section, Dept. of Public Services, Minneapolis 1.	Pamphlets and information on suggested projects and programs in health education, for use with biology.

Address (continued)	*Annotation (continued)*
General Motors Corporation, Department of Public Relations, 3044 W. Grand Blvd., Detroit 2.	Illustrated pamphlets on physical science subjects for high school use. Excellent for promotion of group discussions.
B. F. Goodrich and Company, Public Relations Dept., Akron 18, Ohio.	Illustrated rubber display chart and other materials available.
Goodyear Tire and Rubber Company, Public Relations Dept., Akron 16, Ohio.	Photographs and teaching materials on rubber for secondary science teachers.
Greyhound Information Center, 113 St. Clair Ave., N.E., Cleveland 14, Ohio.	"Highway Transportation on Parade" and other travel information, especially good on the national parks.
Hawaiian Pineapple Company, 215 Market St., San Francisco 6.	Literature illustrative of Hawaiian pineapple growing, for economic botany and biology.
Hayden Planetarium, 81st St. at Central Park West, New York 24.	Inexpensive star-explorer charts and other materials for teaching astronomy. List on request.
H. J. Heinz Company, Public Relations Dept., 1052 Progress St., Pittsburgh 12.	"Nutritional Data" and other bulletins and charts. Also a quarterly bulletin: *Nutritional Observatory.*
Hershey Chocolate Company, 19 E. Chocolate Ave., Hershey, Pa.	Large chart materials and pamphlet issues of interest to teachers of botany and biology.

Address (continued)	*Annotation (continued)*
International Harvester Company, Public Relations Dept., 180 N. Michigan Ave., Chicago 1.	Booklets and pamphlets for use with classes in general science and general biology. Materials free to teachers.
International Nickel Company, Inc., Development and Research Division, 67 Wall St., New York 5.	Pamphlets for use with high school general science and chemistry study groups. Free to teachers on request. Valuable material for stimulation of discussions.
International Paper Company, 220 E. 42d St., New York 17.	Pamphlets on forestry and wood pulp, of interest to students of economic biology and botany.
Izaac Walton League of America, 31 N. State St., Chicago 2.	Pamphlets on fishing and fish conservation for use of classes in zoology and social biology.
Kellogg Company, Home Economics Dept., Battle Creek, Mich.	Illustrated pamphlets on cereals, of interest to students of social biology and botany.
Knox Gelatine Company, Public Relations Dept., Johnstown, N.Y.	Pamphlets and chart materials for use of biology teachers.
Kraft Cheese Company, Advertising Dept., 500 Peshtigo Ct., Chicago 90.	Pamphlets and pictures illustrating the preparation of cheese, for use of zoology and social biology classes.
Lehigh Navigation Coal Company, 123 S. Broad St., Philadelphia 9.	Illustrated pamphlets available on coal, for general science class use.

Address (continued)	*Annotation (continued)*
E. Leitz, Inc., 304 Hudson St., New York 13.	Charts and pamphlets on optics, cameras, and use of scientific instruments.
Louisiana Dept. of Agriculture, 541 St. Anne St., New Orleans 16.	Demonstration exhibits of rice, for use with botany and social biology classes.
Mallinckrodt Chemical Works, Second and Mallinckrodt Sts., St. Louis 7.	Illustrated outline of the *History of Chemistry* from the pre-Christian era to the present, in wall-chart form.
Maple Manufacturer's Association, 46 Washington Blvd., Oshkosh, Wis.	Booklets and pamphlets on uses of maple wood, useful for botany and social biology classes.
Masonite Corporation, Advertising Dept., 111 W. Washington St., Chicago 2.	Information on hardboard and its uses, of interest in botany and social biology.
Massachusetts Institute of Technology, Director of Admissions, 69 Massachusetts Ave., Cambridge 39, Mass.	"Educational Opportunities," "Biology Today and Tomorrow," and other illustrated pamphlets, useful in stimulating interest in scientific careers.
Metropolitan Life Insurance Company, School Service Dept., 1 Madison Ave., New York 10.	An extensive series of excellent health bulletins, available to high school teachers of biology upon request.

Address (continued)	*Annotation (continued)*
Millers' National Federation, Wheat Flour Institute, 309 W. Jackson Blvd., Chicago 6.	Descriptive leaflet detailing the pamphlets and teaching aids prepared for use of secondary teachers.
Minnesota Mining and Manufacturing Co., Educational Dept., St. Paul 6.	Pamphlets on sound recording, of interest to instructors of general science and physics.
Monsanto Chemical Company, Public Relations Dept., 1700 S. Second St., St. Louis 4.	Excellent materials on chemicals and plastics, with emphasis upon applied results of scientific methods. Useful in chemistry, physics, and biology.
National Audubon Society, 1000 Fifth Ave., New York 28.	Free and authoritative materials for bird study and general conservation in high school classes.
National Committee on Conservation, 1409 Garfield St., Laramie, Wyo.	Publications on conservation teaching, of interest to teachers of social biology, botany, and agriculture.
National Cotton Council of America, P.O. Box 18, Memphis 1.	Pamphlets and posters on cotton, for use of teachers and students in botany and social biology.
National Geographic Society, Educational Dept., Sixteenth and M Sts., N.W., Washington 6, D.C.	"Geographic School Bulletins," maps, and pamphlets on a wide variety of scientific subjects. Write for free lists.

Address (continued)	*Annotation (continued)*
National Parks Association, 1214 Sixteenth St., N.W., Washington 6, D.C.	Charts and pamphlets on the national parks, together with issues of the *National Parks* magazine.
National Science Teachers Association, 1201 Sixteenth St., N.W., Washington 6, D.C.	Valuable science teaching packets sent without charge to members. Write for details of the plan.
National Tuberculosis Association, 1790 Broadway, New York 19.	"Some Suggestions for Writing Health Materials," and other pamphlets of general interest to science teachers.
National Wildlife Federation, 3308 Fourteenth St., N.W., Washington 10, D.C.	Conservation education information for teachers of biology, botany, and zoology in secondary schools.
New York Central System, Public Relations Dept., 466 Lexington Ave., New York 17.	Pamphlets illustrative of various phases of rail transport, for use with general science students. Also of interest in social biology classes.
Office of Education, Science Education Division, Federal Security Agency, Washington 25, D.C.	Pamphlets for secondary science educators, including information on research studies.
Oklahoma Planning and Resources Board, 318 Capitol Office Building, Oklahoma City.	Pamphlets advocating domesticated forests as a solution to the problem of dwindling timber resources.
Pacific Lumber Company, 122 E. 42d St., New York 17.	Booklets and informational material on insulation wool and its various uses in industry.

Address (continued)	*Annotation (continued)*
Pan American World Airways, Educational Director, 135 E. 42d St., New York 17.	Pamphlets, pictures, and posters, courses of study, and film library list on air education.
Peter Cailler-Kohler, Swiss Chocolate Company, 60 Hudson St., New York.	Pictures, charts, and booklets about chocolate for students of economic botany and biology.
Pittsburgh Plate Glass Company, Public Relations Division, 632 Duquesne Way, Pittsburgh 22.	"Color Dynamics" and other instructional material on the physics of color. Excellent physical science classroom material.
Quaker Oats Company, Advertising Dept., 141 W. Jackson Blvd., Chicago 4.	Nutrition charts and cereal health food pamphlets for use of general science, biology, and botany classes.
Radio Corporation of America, Educational Services Division, Camden, N.J.	Literature on radio, television, radar, and electron microscopes. Excellent for stimulation of physics students.
Save-the-Redwoods League, 250 Administration Building, University of California, Berkeley 4, Calif.	Illustrated pamphlets on redwood properties, uses, and conservation problems, for teachers of botany.
Science Clubs of America, 1719 N St., N.W., Washington 6, D.C.	Pamphlet detailing how to participate in the National Science Fair and the program of the Science Clubs of America.

Address (continued)	*Annotation (continued)*
Science Educational Service, Science Publications, 201 N. School St., Normal, Ill.	Lists of teaching materials for general science, biology, chemistry, and physics.
Shell Oil Company, Public Relations Dept., 50 W. 50th St., New York 20.	Pamphlets and teaching charts illustrative of modern petroleum research for general science and chemistry.
Society of American Foresters, Seventeenth St. and Pennsylvania Ave., N.W., Washington 6, D.C.	Forest-conservation materials for high school science educators.
Soil Conservation Service, Department of Agriculture, Washington 25, D.C.	Pamphlets and pictures on soil conservation for biology and agriculture.
Southern Hardwood Producers, Inc., 805 Sterick Building, Memphis 3.	Informative illustrated booklets, useful for students of botany.
Southern Pacific Lines, Public Relations Dept., 310 S. Michigan Ave., Chicago 4.	Pictorial material on transportation and southwestern United States for teachers of general science.
Southern Pine Association, Canal Building, New Orleans 4.	Booklets and pamphlets on southern pines, useful for botany classes.
Standard Oil Company of California, Education Section, Public Relations Dept., 225 Bush St., San Francisco 20.	Informative bulletins and pamphlets, useful in general science and chemistry classes. In writing, give specific information as to proposed uses.

Address (continued)	*Annotation (continued)*
State Teachers' Magazines, 307 N. Michigan Ave., Chicago 1.	Booklets on atomic energy, health education, and other topics. A centralized source for teachers.
Swift and Company, Educational Division, Agricultural Research Dept., Chicago 9.	Pamphlets of interest to teachers and students of biology, botany, and economic zoology.
Sylvania Electric Products, Inc., Dept. L-4010 A, 1740 Broadway, New York 19.	Information concerning fluorescent lighting, for general science, chemistry, and physics classes.
Tanners' Council of America, Inc., 100 Gold St., New York 7.	Pamphlet materials for economic zoology classes.
Taylor Instrument Company, Public Relations Dept., Rochester 1, N.Y.	Pamphlets on weather for general science teaching.
Teachers' Material Service, New Bedford, N.Y.	Actual samples of science teaching materials. Price list on request.
The Wool Bureau, Inc., 16 W. 46th St., New York 19.	Bibliography of wool literature (price list), "The Story of Wool," and other pamphlets, with statistical charts.
Timber Engineering Company, 1319 Eighteenth St., N.W., Washington 6, D.C.	"Wood Study Kit" and "Booklet of Experiments" for botany classes. Write for price list.

Address (*continued*)	*Annotation* (*continued*)
Transcontinental and Western Air Lines, Inc., Public Relations Dept., 10 Richards Rd., Kansas City, Mo.	Pamphlets, maps, and picture post cards, free on request to general science and physics teachers.
Union Bag and Paper Corporation, Woolworth Building, New York 17.	Educational pamphlets for economic botany and social biology.
Union Carbide and Carbon Corporation, Public Relations Dept., 30 E. 42d St., New York 17.	Information concerning chemicals, carbons, and plastics; their uses in science and in industry, for general science and chemistry.
United Air Lines, School and College Service, Address the nearest office: 80 E. 42d St., New York 17. 35 E. Monroe St., Chicago 3. 6th and Olive Sts., Los Angeles 14. 400 Post St., San Francisco 2. 1225 Fourth Ave., Seattle 1.	Bulletin-board materials, teaching aids, and motion-picture films, available on a free loan basis. Pictures of historic planes, time tables, air maps, air-express folders, color prints, and other excellent aids for science education, all free to teachers. Send for free list and order blank, stating use with secondary school students of general science and/or physics.
United Fruit Company, Educational Service Dept., Pier 3, North River, New York 6.	Materials on bananas for high school social biology and botany.

Address (continued)	*Annotation (continued)*
U.S. Department of Agriculture, Division of Publications, Office of Information, Washington 25, D.C.	*List of Available Publications of the United States Department of Agriculture* containing complete titles and order numbers of publications free and for sale.
U.S. Department of Commerce, Weather Bureau, Washington 25, D.C.	Weather maps and cloud-formation pictures, free to teachers of general science.
U.S. Forest Service, Department of Agriculture, Washington 25, D.C.	"Material of Interest to Teachers" listing many pamphlets and leaflets.
U.S. Government Printing Office, Superintendent of Public Documents, Washington 25, D.C.	*Price Lists* of government publications sent free upon request to high school teachers.
United States Pulp Producers Association, 122 E. 42d St., New York 17.	Pamphlets on wood-pulp industry for use of botany classes.
United States Rubber Company, Rockefeller Center, 1230 Avenue of the Americas, New York 20.	Pamphlets on rubber for high school students of chemistry and economic botany.
United States Steel Corporation, Department of Research and Public Relations, 429 Fourth Ave., Pittsburgh 19.	"Science in Steelmaking" and other pamphlet instructional material of interest to chemistry and physics teachers in American secondary schools.

Address (*continued*)	*Annotation* (*continued*)
Universal Scientific Company, Inc., 1102 Shelby St., Vincennes, Ind.	Descriptive literature concerning teaching of electronics or electricity.
Wallace and Tierman Company, Public Relations Dept., Newark 1, N.J.	Pamphlet materials on chlorination, informative to students of high school chemistry.
West Coast Lumbermen's Association, 1410 S.W. Morrison St., Portland 5, Ore.	Printed educational materials for use of botany students.
Western Association of Railway Executives, Public Relations Dept., 105 W. Adams St., Chicago 3.	Pictures, teachers' manual, and instruction kit on rail transportation, for general science classes in junior and senior high schools.
Western Pine Association, Department 16, 510 Yeon Bldg., Portland 4, Ore.	Booklets and pamphlets about pines, firs, cedars, and spruce. Price lists on request.
Westinghouse Electric Corporation, School Service Division, 306 Fourth Ave., Pittsburgh 30.	"Teaching Aids," bulletin issued free to teachers, details the many excellent aids obtainable for secondary science education.
Wilderness Society, 1840 Mintwood Pl., N.W., Washington 9, D.C.	Conservation of natural resource information for botany, biology, and zoology classes.
Wild Flower Preservation Society, 3740 Oliver St., N.W., Washington 15, D.C.	Informational pamphlet materials on wild-flower conservation, of interest to botany teachers.

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[1] Professional Methods Bibliography presents for the guidance of teachers-in-training, as well as for teachers-in-service, many excellent publications in secondary science methods. In addition, suggested modern references in allied fields are incorporated, following the social science–natural science integrating theme evident throughout the text. Included are carefully evaluated works on educational psychology and sociology, anthropology, adolescent guidance, personality development, general secondary methods, measurement, and kindred references useful in building a well-rounded developmental program in terms of student preparation for advanced studies, as well as for life in a democratic world society.

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